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Sewage Works

INCINERATION PROBLEMS *

By George J. Schroepfer

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The relatively rapid development of sewage sludge incineration has indeed brought with it some problems, both operational and financial. The author's interest in the latter phase has caused him to stress this part of the subject. Perhaps the discussions will more aptly cover the former. Another portion of this subject, which the author chose to call a problem, has also been covered. This relates to the broad decisions which must be made in advance planning in a particular situation where sludge incineration is under consideration. These decisions are extremely important from an economics standpoint, and were believed to justify more space than problems of operation which have become more or less standardized, and which—except to the operator—are of relatively minor importance.

Early History

While sewage sludge incineration as we now visualize it has an experience record of about twelve years, the literature on the subject is replete with references to early efforts and practice in the burning of this material. Streander (22) refers to several plants in England and Germany which burned sewage sludge, usually with garbage, as far back at 1910. He also refers to screenings incineration at Reading, Pa., and at Long Beach, Calif., in 1916.

It is interesting to mention a reference to an article in the first volume of This Journal in which the first President of the Federation discusses an early effort at sewage sludge burning. Emerson (1) states: "In at least one instance sludge has been burned on the bed (sludge drying) without objectionable odor, by building a grass fire on the surface. The resulting ash was removed at an expense estimated at about one-fourth that for unburned sludge."

The first case of actual sludge incineration which the writer witnessed was in 1930 in a midwestern sewage plant. Because of the unavailability of funds to purchase fuel, the ingenious operator (necessity being actually the mother of invention, in this case) was burning air-dried sludge in his heating boiler to provide heat for the plant.

Rudolfs and Baumgartner (2) conducted experiments in the incineration of sewage sludge and slag as far back as 1931. The same senior author and Cleary (4) refer to experimental spray drying and incineration at Poughkeepsie, N. Y., in 1931. The authors state: "Engineers are much interested in dewatering and incineration because it would appear that the difficult sludge problem may be solved permanently, efficiently and possibly at lower cost. However, much work remains to be done before the goal is attained."

Townsend (3) refers to incineration of grit and screenings at Milwaukee beginning in 1932. In discussing possible solutions to the sludge disposal problem at Dearborn, Mich., Owen (31) states: "Work has been done (1932) on incineration. It is hoped that in the very near future a furnace will be installed. The writer has always been

* Presented at 19th Annual Meeting, Federation of Sewage Works Assns.; Toronto, Ontario, Canada; October 7–9, 1946.

in favor of this method, and believes this to be the ultimate answer to the sludge problem in all plants."

As has been the case with so many developments in sewage treatment and sludge disposal, The Sanitary District of Chicago contributed greatly to the developments in this field. Mohlman (8) refers to the experimental operation of a large scale rotary dryer and incinerator at the West Side plant in Chicago from August 5, 1932 to May 18, 1933.

TABLE I.—Sludge Incineration Installations in the U. S.; 1934–1946

Number	Type	Year Installed or Initial Operation	Location	Capacity (Tons Cake Daily)	Type of Sludge
1	B	1934	Dearborn, Mich.	50	R; C
2	A	1935	Chicago, Calumet	200	A
3	B	1936	Kokomo, Ind.	20	D; T
4	B	1936	Auburn, N. Y.	29	R; C
5	B	1936	LaPorte, Ind.	11	D; T
6	B	1936	Colorado Springs, Col.	22	D; C
7	B	1936	New Britain, Conn.	62	R; B; C
8	B	1936	Elmira, N. Y.	38	R; C
9	A	1937	Neenah-Menasha, Wis.	35	R
10	B	1937	Kaukauna, Wis.	33	R; C; G
11	B	1937	Cleveland, Westerly	94	D
12	B	1937	Middletown, Conn.	12	D
13	B	1938	Mpls.-St. Paul, Minn.	720	R or C
14	B	1938	Greece, N. Y.	15	R; A; G
15	B	1938	Cleveland, Southerly	400	D; A; T
16	B	1938	Conshohocken, Pa.	14	R or C; G
17	A	1938	Buffalo, N. Y.	140	D
18	B	1938	Barberton, Ohio	30	R or C
19	A	1938	Tenafly, N. J.	3*	A
20	B	1938	Columbus, Ohio	70	D; A
21	B	1939	Wyandotte, Mich.	80	R; D
22	B	1939	Detroit, Mich.	1,320	R; D
23	B	1939	Ashland, Ohio	10	R or C
24	A	1939	Chicago, Southwest	1,875	A
25	B	1939	Anderson, Ind.	60	R; G
26	B	1939	Thompsonville, Conn.	29	R
27	B	1939	Piqua, Ohio	14	R; G
28	B	1939	New Haven, Conn.	40	D
29	B	1939	Dayton, Ohio	47	D; T
30	B	1939	New Haven, Conn.	43	R
31	A	1940	Watervliet, N. Y.	4.5*	R
32	B	1940	Rock Island, Ill.	24	D; G
33	A	1940	Cuyahoga Falls, Ohio	8.4	B
34	A	1940	Springfield, Mass.	32	D
35	B	1941	Cranston, R. I.	48	D; A
36	A	1941	Duluth, Minn.	26	D
37	A	1941	Manitowoc, Wis.	4*	D
38	A	1943	San Diego, Cal.	63*	D
39	A	1944	Battle Creek, Mich.	28*	D
40	A	1944	Stamford, Conn.	18*	D
41	B	1945	East Chicago, Ind.	84	D; B
42	B	1945	Dearborn, Mich.	80	R; C
43	A	1946	Sheboygan, Wis.	36	D
44	A	—	Chicago, West Southwest	625	A

* Drying only.

Type incineration: A—flash drier; B—multiple hearth. Type sludge: R—raw primary; A—activated; C—chemically precipitated; D—digested; T—trickling filter humus; B—"Biochemical"; G—garbage.

This was followed by experiments on a hammermill dryer which was placed in operation during February, 1934, and after a satisfactory period of testing, was dismantled.

Development and Present Status

The first permanent installation of equipment in the U. S. for the incineration of sewage sludge occurred in 1934, at Dearborn, Michigan. This installation of the multiple hearth type was placed into operation in February, 1935, closely followed by the Chicago Calumet incinerator of the flash-drying type, which was placed into operation in December of the same year.

Indicating a need for development in the methods of sludge disposal, the growth of incineration has been very rapid, as shown by Table I which lists the installations of the flash dryer and multiple hearth types in the period 1934–46, readily available to the author. This list is perhaps not complete, but includes 44 incinerator installations in 39 communities. Table II shows the development by years and contains cumulative totals, of the number and capacities of the above installations.

To indicate the proportion of the sludge produced in the U. S. which is incinerated, as compared to that which is disposed of by other means, the following is presented. In 1942 approximately 42,000,000 persons resided in the 5,610 communities served by sewage treatment plants. Since about one-half of these plants provide partial treatment, and the remainder complete treatment, the average removal of suspended solids might be taken at approximately 70 per cent. At a concentration of 0.2 lb. suspended solids per capita per day in the raw sewage, the total removal of suspended solids by these plants might be approximately estimated at 3,000 dry tons per day. The total capacity of existing incineration plants is approximately 6,000 tons of cake solids daily, or at 30 per cent dry solids, 1,800 tons of dry solids daily. If the average load incinerated were 40 per cent of capacity, the total tonnage of dry solids incinerated daily would be 700 tons, compared with the estimated total removal of 3,000 tons daily in all existing plants, or about 20 to 25 per cent of the sludge produced in all the plants in this country. Viewed in another way, the total 1940 population in all the cities having sewage sludge incinerators in 1946 is 9,235,000, or about 20 per cent of the population served by sewage treatment plants.

TABLE II.—Development of Sewage Sludge Incineration

Year	New Plants During Year		Cumulative Totals	
	Number	Tons Cake Daily	Number	Tons Cake Daily
1934	1	50	1	50
1935	1	200	2	250
1936	6	182	8	432
1937	4	174	12	606
1938	8	1,392	20	1,998
1939	10	3,518	30	5,516
1940	4	69	34	5,585
1941	3	78	37	5,663
1942	—	—	37	5,663
1943	1	63	38	5,726
1944	2	46	40	5,772
1945	2	164	42	5,936
1946	1	36	43	5,972

A distribution of incinerator locations by populations in the communities served by them is of interest:

Population Range	Number of Cities
0–10,000	3
10,000–20,000	6
20,000–50,000	16
50,000–200,000	6
Over 200,000	8

Incineration plants are located in communities as small as 500 population (Greece, N. Y.) to as large as Chicago with a population of about 3,400,000 in 1940. Approximately 20 per cent are located in communities of less than 20,000 population.

A Dozen Years of Incineration Experience

Almost 12 years have elapsed since this field was braved and the first plant unit was placed into operation at Dearborn. Somewhat earlier (1932), the visitors who came to inspect the large scale experimental plant in Chicago broached these questions: Will it really burn? Will it smell? Will there be a smoke nuisance? What will it cost? The answers to the first three questions have, of course, been found. The last question has at least partially been answered.

In operations during early years a number of problems were encountered and successfully overcome. This applies equally to both types of incinerators. The literature contains references, among others, to difficulties due to abrasion of the ducts, cyclones and fans in incinerators of the flash drying type. In the case of the multiple hearth type, problems have been encountered principally in the preheaters and in overheating of arms and burning, or overheating of teeth, especially where raw sludge (with an excess of heat) was incinerated. Permanent or partial solutions have been found to most of these problems. The early plants bore the brunt of the development pains, leaving to later plants the task of improving the efficiency of operation and of reducing costs.

Minneapolis-St. Paul Experience

The writer would prefer to speak specifically rather than generally about operating problems. Having been fortunate to be connected with the operation of one large incineration plant for eight years, he desires to record in summary form some of the experiences over this period in the operation of the Minneapolis-St. Paul plant. Feeling that basically the experience with a particular unit is best and ultimately represented in the cost record, such data are presented in Table III. This table covers the period from August, 1938, to December, 1944, inclusive. Considering the 5-year period from 1940 to 1944, inclusive, the cost of operation and maintenance per ton of cake and of dry solids was \$0.42 and \$1.26, respectively. Of the total operation and maintenance cost, 30.5 per cent was expended for maintenance and the balance for operation. The operating expense can be further distributed as follows:

Salaries and wages	70.0%
Materials and supplies	12.8%
Power and light	17.2%

In this period of eight years no problems from the odor and fly ash nuisance standpoint presented themselves. Fly ash is satisfactorily removed by a large capacity gravity dust settling flue. It is interesting however to mention a condition of smoke nuisance which occurred for several months, caused not by the design of the incinerators but by a faulty operation procedure into which the operators gradually degenerated. Finding that "starving" the furnaces of air resulted in much easier operation of the furnaces (for a time) the operators went further in this direction until only a negligible quantity of combustion air was admitted, and as a result an appreciable quantity of unburned gases of high smoke content was discharged from the stack. Along with this, extremely high temperatures (2400° F. +) were measured by an optical pyrometer in the combustion zone, resulting in fusion of the ash and drooping of the arms. Observing the additional work to which they were put by this faulty operation, the operators gladly cooperated with the front office, and thereupon the smoke, ash fusion, and arm difficulties immediately disappeared.

The removal in 1941–42 of the preheaters, which continually filled with scale—causing a high power cost—simplified operations greatly and mark-

TABLE III.—Incineration Data, Minneapolis-St. Paul Sanitary District—1938–1944

Item	1938	1939	1940	1941	1942	1943	1944	5-Year Average (1940–44)
Filter cake (wet tons daily)	172.0	303.3	308.3	309.4	286.9	277.5	292.6	294.9
Filter cake (dry tons daily)	58.6	103.3	108.4	108.3	96.6	92.8	94.7	100.2
Tons dry solids incinerated annually	10,248	35,028	37,091	35,993	33,838	32,955	33,758	34,727
Power (kw. hr. per ton dry solids)	18.5	17.0	17.0	14.0	8.8	4.7	6.7	10.2
Fuel oil (gal. per ton dry solids)	3.7	2.31	2.38	1.83	2.15	1.99	2.56	2.18
Tons cake solids incinerated annually	28,793.1	107,835.8	112,854.7	108,912.4	99,654.0	96,830.0	101,979.5	104,046.1
Incineration costs ($):								
Operation	19,233.60	32,393.09	35,697.84	27,007.48	29,517.16	29,594.49	30,647.65	30,492.70
Maintenance	1,808.60	4,691.93	14,524.63	13,522.59	10,062.18	16,268.22	12,165.01	13,308.13
Total	21,042.20	37,085.02	50,222.47	40,530.07	39,579.34	45,862.71	42,812.66	43,800.83
Distribution of operating expense:								
Salaries and wages	—	—	20,282.84	21,111.16	20,197.15	22,659.65	23,315.74	21,513.31
Materials and supplies	—	—	5,606.83	3,067.67	4,073.46	3,250.08	3,587.13	3,917.03
Power and light	—	—	9,489.92	7,765.11	5,246.55	3,684.76	3,744.78	5,986.22
Total incineration cost (per ton of cake)	0.73	0.35	0.45	0.37	0.40	0.47	0.42	0.42
Total incineration cost (per dry ton)	2.05	1.06	1.35	1.13	1.17	1.39	1.27	1.26

edly reduced operation and maintenance costs. Because of the excess of heat available from the type burned, some difficulty had been experienced with the rabble arms on one or two "hot" hearths of the furnaces. This difficulty has now to a large extent been overcome. The original central shafts are still in service in all units. Several hearths have been "jacked-up" and some brick replaced. These problems and resultant costs have been reasonably within the range of what might be expected in the incineration of material of this type, as shown by the relatively low costs of operation and maintenance.

It had been difficult during most of this period to get away from variations in rate of combustion, and with it, variations in temperature. Some variations in tonnage and moisture content of the sludge from the vacuum filters occurred, as affected by removing and returning filters from and to service. This resulted in variation in feed, which was aggravated in the incinerator to the extent that combustion rates were possibly 100 per cent above and below the feed rate. Furthermore, this caused a variation in the quantity of water used for cooling, in turn cutting down the combustion air, thereby further multiplying the variation problem. A marked improvement was indicated when the vacuum filters were revamped so that they could be washed while in service, thereby resulting in much more uniform quantity and quality of filter cake. In this problem a preparatory unit could be blamed for much of the incineration difficulty.

The writer's general opinion based on this period of operation with the type of incinerator employed, is that incineration offers an economical solution to the final sludge disposal problem under the conditions obtaining in this plant. The truth of this was brought forceably to the author's attention during the war period when, as it seemed likely that incinerator parts might not be procurable, bids were received from contractors to haul the sludge a distance of 1,000 to 2,000 ft. and cover it with earth. The lowest price was $0.60 per ton compared to the cost of incineration and ash disposal of $0.42 per ton. It was definitely a financial relief not to have to resort to this expedient. Viewing the cost situation broadly, it is not likely that a method can be developed which will reduce materially costs of incineration below this low figure. Furthermore, the ultimate in cost reduction has not yet been attained in the case of incineration.

Construction Cost

In making comparisons with other or older methods of sludge disposal, one element of consideration is the first, or construction cost of sludge incineration. It is evident that the construction cost of such incinerators will vary widely as affected by a number of factors. Some of these are the usual ones which are common to all construction and equipment costs; others are inherent in the particular problem of sludge incineration. Among these may be mentioned the type, the inclusiveness of the proposal as it relates to appurtenant items, such as belt conveyors and ash handling equipment, covered (to mention but two), the characteristics of the sludge as related to moisture and volatile content, etc.

It would be expected, therefore, that a relatively wide variation would occur in this cost item. Figure 1 shows this variation and indicates usual average costs of equipment installed (but not enclosing structures). In general, the following summarizes the average cost per ton of capacity for incinerator equipment installed:

Capacity (tons per day)	Cost per Ton ($)
10	2,000
50	1,200
100	1,000
500	600
1,000	450

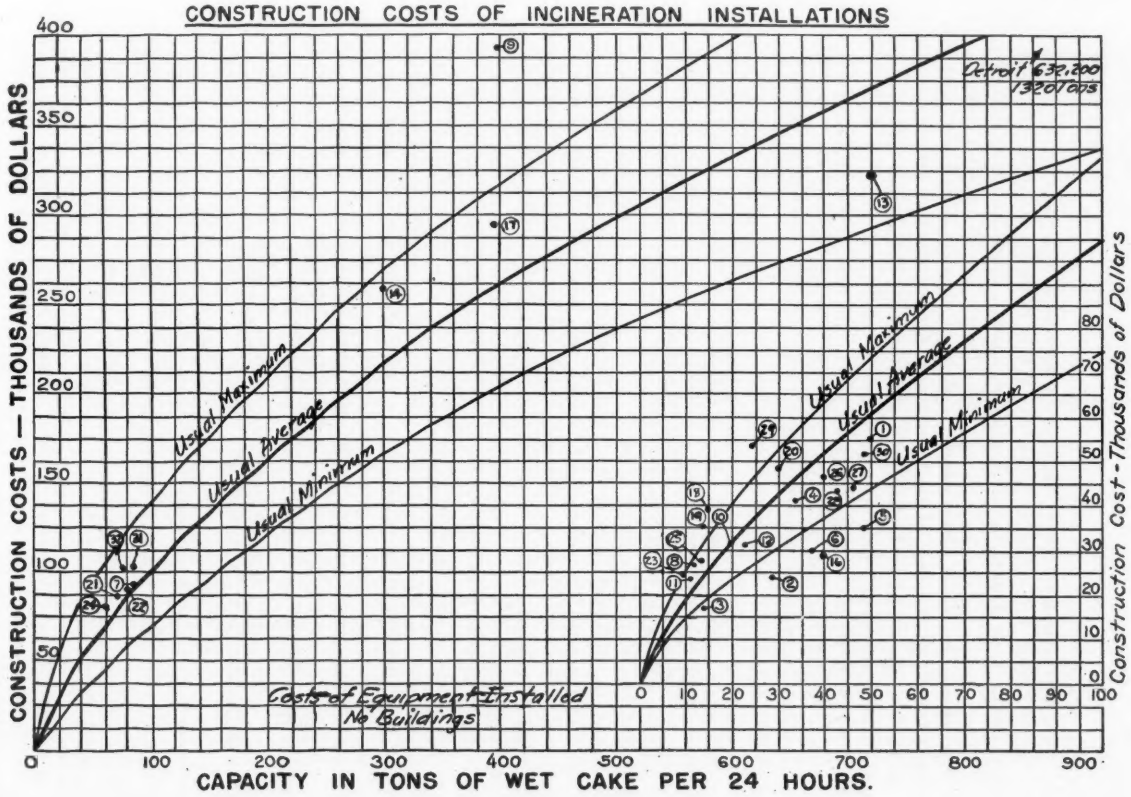
CONSTRUCTION COSTS OF INCINERATION INSTALLATIONS
CONSTRUCTION COSTS — THOUSANDS OF DOLLARS
Construction Cost - Thousands of Dollars
CAPACITY IN TONS OF WET CAKE PER 24 HOURS.
Usual Maximum
Usual Average
Usual Minimum
Detroit $32,200 1320 Tons
Costs of Equipment Installed No Buildings

FIGURE 1.—Construction costs of sludge incineration installations. Point No. 14 represents flash drier type; all others multiple hearth.

As indicated in the chart the usual range in equipment costs is 25 per cent above and below the values given. The construction costs for the 32 plants shown are—with the exception of one plant—for equipment of the multiple hearth type, costs values for the flash drying type being unavailable from the manufacturer or from the literature.

To the above installed equipment costs must be added the cost of buildings to enclose the units. Generally the cost of structures will be approximately 25 to 50 per cent of the equipment costs, depending on the type of equipment, foundation conditions, architectural simplicity or elaborateness, etc.

Operation and Maintenance Cost

Here again a number of influencing factors affect the cost of operation and maintenance in different plants and from time to time in the same plant. Realizing that there is reason for a wide spread in annual costs at typical installations, Table IV is presented. Unfortunately a search of the literature and a study of many annual reports reveals only 7 plants at which operation and maintenance costs are available. Most plants do not present a sufficient breakdown of costs in their annual reports to permit of determining incineration costs. In fact, the author was astounded to encounter several annual reports without so much as a mention of plant operating costs, much less incineration costs. It is unfortunate that more data are not available on the 44 plants employing incineration; it is hoped that supplementary data may be presented in the discussion of this paper.

While it would be expected that the operation and maintenance costs would be greater in the smaller plants, the data available, possibly because of their insufficiency, do not support such a statement. The costs in the seven plants are as follows:

	Cost Per Ton ($)	
	Cake Solids	Dry Solids
Average	1.19	3.71
Maximum	1.68	5.50
Minimum	0.38	1.12

Because of the paucity of cost data, and the availability of a record of operation at the Buffalo plant to compare with the Cleveland Southerly and Minneapolis-St. Paul plants, a special comparison has been prepared and is presented as Table V. This special table was prepared because, while the records at the Buffalo plant are generally very thorough and complete, they do not furnish a distribution as between filtration and incineration costs. The table permits of some general comparisons on a cost per dry ton basis which are summarized below:

	Buffalo	Mpls.-St. Paul	Cleveland Southerly
(1) Average total cost of sludge disposal (5 years)	$10.56	$3.38	$11.28
(2) Cost excluding chemicals for sludge conditioning	8.84	2.64	8.86
(3) Cost of incineration	—	1.27	5.06
(4) Cost of labor, power, material and supplies for vacuum filtration	—	1.37	3.80
(5) Cost of incineration assuming cost of item (4) as in Mpls.-St. Paul plant	7.47	—	—
(6) Ditto if costs as in Cleveland Southerly plant	5.04	—	—

TABLE IV.—Operation and Maintenance Costs of Sewage Sludge Incineration

Plant	Tons Cake Daily	Dry Tons Daily	Annual Cost Operation and Maintenance ($)	Cost per Ton Cake ($)	Cost per Ton Dry Solids ($)	Period Covered and Remarks
Detroit, Mich.[1]	555.0	173.5	282,870.46	1.40	4.44	Year ended June 30, 1944
Minneapolis-St. Paul, Minn.[1]	294.9	100.2	43,800.83	0.42	1.26	5 year average; 1940–44
Springfield, Mass.[2]	9.8	3.43	6,900.00	1.92	5.50	To May, 1944; beginning not stated
Dearborn, Mich.[1]	31.5	10.8	4,380.00	0.38	1.12	1935 and 1936
Duluth, Minn.[2]	5.1	1.47	2,089.52	1.12	3.90	1944
	5.0	1.60	2,386.87	1.34	4.10	1941
Cleveland-Southerly, Ohio[1]	119.0	34.0	55,074.75	1.25	4.45	1941
	138.0	38.6	77,664.30	1.55	5.50	1942
	106.0	48.5	126,402.28	2.10	7.15	1943
	139.0	39.0	61,922.72	1.20	4.40	1944
	166.0	46.7	65,567.02	1.10	3.80	1945
	—	—	—	1.44	5.06	Average 5 years
	—	—	—	1.28	4.55	Average 4 years; excl. 1943
Cleveland-Westerly, Ohio[1]	28.0	9.20	—	1.68	5.10	Period not stated

[1] Multiple hearth type. [2] Flash drier type.

TABLE V.—Comparison of Sludge Disposal Costs at Three Plants

Plant	Period Covered	Total Sludge Disposal				Cost of Sludge Disposal—Excluding Chemicals for Sludge Conditioning			
		Annual Cost[1] ($)	Tons Cake	Tons Dry Solids	Cost per Dry Ton ($)	Annual Chemical Cost[1] ($)	Cost Less Chemicals[1] ($)	Cost per Dry Ton ($)	Cost of Incineration Only ($)
Buffalo, N. Y.	1940–41	109,000	29,000	10,700	10.20	18,382	91,000	8.50	—
	1941–42	112,000	32,295	11,900	9.50	20,917	91,000	7.70	—
	1942–43	112,000	26,627	10,000	11.20	15,269	97,000	9.70	—
	1943–44	119,000	29,503	10,700	11.10	17,545	102,000	9.60	—
	1944–45	119,000	29,873	11,100	10.80	22,443	97,000	8.70	—
Average	1940–45	—	—	—	10.56	—	—	8.84	—
Mpls.-St. Paul, Minn.	1941	117,740	108,912	35,993	3.27	33,410	84,000	2.35	1.13
	1942	110,708	99,654	33,838	3.27	25,431	85,000	2.50	1.17
	1943	116,606	96,830	32,955	3.53	23,416	93,000	2.80	1.39
	1944	112,532	101,980	33,758	3.33	23,257	89,000	2.65	1.27
	1945	113,488	97,703	32,461	3.49	18,846	94,000	2.90	1.38
Average	1941–45	—	—	—	3.38	—	—	2.64	1.27
Cleveland-Southerly, Ohio	1941	139,000	43,433	12,420	11.20	31,000	108,000	8.70	4.45
	1942	167,000	50,217	14,091	11.80	33,000	134,000	9.50	5.50
	1943	224,000	60,427	17,673	12.70	35,000	189,000	10.70	7.15
	1944	157,000	50,462	14,179	11.10	39,000	118,000	8.30	4.40
	1945	162,000	60,202	17,125	9.50	40,000	122,000	7.10	3.80
Average	1941–45	—	—	—	11.26	—	—	8.86	5.06

[1] Costs rounded off.

TABLE VI.—Comparison of Garbage and Sewage Sludge Incineration Costs

Capacity of Plant (tons per day)	Construction Cost ($)			Garbage (or Sludge) Incinerated (tons per day)	Operation and Maintenance Costs ($)		
	Usual Minimum	Usual Average	Usual Maximum		Usual Minimum	Usual Average	Usual Maximum
Garbage Incineration—Equipment and Buildings[1]							
10	4,500	9,000	25,000	5	0.65	1.80	3.40
50	19,000	39,000	105,000	10	0.55	1.65	3.30
100	35,000	71,000	200,000	50	0.45	1.32	2.50
500	150,000	310,000	800,000	100	0.39	1.18	2.25
1,000	280,000	580,000	1,500,000	300	0.32	1.00	1.90
Sewage Sludge Incineration—Equipment Only, No Buildings[2]							
10	15,000	20,000	25,000	5–10[4]	0.70	—	1.35
50	45,000	60,000	75,000	30[4]	0.40	—	1.70
100	70,000	100,000	140,000	150[4]	1.10	1.40	2.10
500	240,000	300,000	360,000	300[4]	0.37	0.42	0.45
1,000	350,000	450,000	520,000	550[4]	—	1.40	—
Sewage Sludge Incineration—Incl. Buildings at 33 Per Cent of Equipment Cost[2, 3]							
10	20,000	27,000	33,000	—	—	—	—
50	60,000	80,000	100,000	—	—	—	—
100	95,000	135,000	185,000	—	—	—	—
500	320,000	400,000	480,000	—	—	—	—
1,000	465,000	600,000	690,000	—	—	—	—

[1] Garbage costs cover period 1925–1930 when *ENR* Index averaged 200.
[2] Sludge incineration costs generally cover period 1935–40 when *ENR* Index varied 200–250.
[3] Plants average $1.19 per ton of cake in plants from 5 to 555 tons of cake per day.
[4] Tons of cake per day.

The above comparison is interesting in that all three plants were placed into operation at about the same time. The deductions made are perhaps subject to question, but may serve to fill the void caused by lack of a complete cost distribution at the Buffalo plant. The above assumptions would indicate an incineration cost at Buffalo of from $5.00 to $7.50 per dry ton.

Comparison of Garbage and Sewage Sludge Incineration Costs

There are some elements of comparability between the incineration of garbage and sewage sludge. In an effort to determine whether costs of the relatively new field of sewage sludge incineration are in line from the construction and operation cost standpoint with garbage incineration experience, Table VI was prepared. The costs of garbage incineration shown are based on a study by the author of 145 installations, generally constructed between 1925–30, when the *Engineering News-Record* Construction Cost Index averaged 200. Summarizing construction costs first, the following are normal averages for the two types.

Capacity (tons per day)	Garbage Incinerators	Sewage Sludge Incinerators
10	$9,000	$27,000
50	39,000	80,000
100	71,000	135,000
500	310,000	400,000
1,000	580,000	600,000

In general, and especially in the smaller installations, the costs of sewage sludge incinerators are somewhat higher than garbage incineration units,

even when consideration is given to the fact that practically all of the sludge incinerators were constructed in the period from 1935–40 when the cost index varied from 200 to 250.

As shown in the table, the annual operation and maintenance cost of garbage incineration varied in the range from \$0.32 to \$3.40, with the normal costs being from \$1.00 to \$1.80 per ton of green garbage in the range from 5 to 300 tons per day. The range in cost of sewage sludge incineration per ton of cake is very close to garbage costs, the maximum cost being \$2.10, the minimum \$0.38, and the average \$1.19.

Fuel Value of Sewage Sludge

The fact that sewage sludge has a fuel value of from 10,000 to 12,000 B.t.u. per lb. of combustible material stimulated early interest in incineration of this material, and has led to the development of processes which in general require a minimum of supplementary fuel. Perhaps the first fundamental work in this field was that by Fair and Moore (23) in 1935. The results of their work for plain settled and activated sludge are summarized in the following tabulation:

Per Cent Volatile	B.T.U. Value per Lb. of Dry Solids	
	Plain Settled Sludge	Activated Sludge
30	2,700	2,800
40	4,000	3,800
50	5,200	4,900
60	6,500	6,000
70	7,800	7,000
80	9,000	8,100
20–90	$85P^{1.085}-700$	$69.2P^{1.085}$

Note: In the above formulae P represents the per cent of volatile matter in dry solids.

The above relationships are borne out by results of analysis covering the year 1940 at the Minneapolis St. Paul Sanitary District. These results are summarized in the following table, which illustrates another factor that must be considered in this connection, viz., that the B.t.u. value per pound of combustible matter varies with the volatile content of the sludge. A marked increase in B.t.u. content on a volatile solids basis with increase in the per cent of volatile solids is observed.

Per Cent Volatile	B.T.U. per Lb. Volatile Solids	B.T.U. per Lb. Dry Solids
40%±2	9,730	3,870
45%±2	9,990	4,500
50%±2	10,460	5,250
55%±2	10,770	5,950
60%±2	10,740	6,450
65%±2	10,900	7,100
70%±2	10,960	7,700

The results covering many years at the Buffalo and Cleveland Southerly plants are interesting in this connection:

	Buffalo	Cleveland Southerly
Years covered	7	6
Per cent volatile	45.0	43.5
B.t.u. per lb. volatile matter	10,300	11,161
B.t.u. per lb. dry solids	4,607	4,850

The results at these three plants, covering raw primary sludge, digested primary sludge, and digested activated and trickling filter sludges, corroborate the work of Fair and Moore, done more than ten years ago.

The volatile content of raw sludge at various plants usually falls in the range from 30 to 80 per cent and of digested sludge from 40 to 60 per cent. Along with this variation the moisture content of filter cake varies in the different plants in the approximate range of 60 to 80 per cent. The combination results in a range of volatile solids per pound of cake from 10 to 30 per cent, or a 300 per cent variation in the heat value of the cake. This

TABLE VII.—Supplementary Fuel Requirements for Incineration

Plant	Fuel Oil per Ton of Cake (gal.)	Gas per Ton of Cake (cu. ft.)	Total B.T.U. in Fuel[1]		Dry Solids in Cake (%)	Volatile in Dry Sol. (%)	Volatile Solids Percentage of Total Cake Solids	B.T.U. per Lb. Cake Solids[2]	Period
			Per Ton Cake	Per Lb. Cake					
Detroit, Mich.[3]	0.21	—	31,500	16	31.1	63.9	19.9	1,990	2 Yrs. (1943–44)
Cleveland Southerly, Ohio[3]	—	440	285,000	143	28.0	45.1	12.6	1,260	2 Yrs. (1944–45)
Mpls.-St. Paul, Minn.[3]	0.74	—	111,000	55	33.9	60.2	20.3	2,030	5 Yrs. (1940–44)
Buffalo, N. Y.[4]	—	830	410,000	205	37.0	47.4	17.5	1,750	5 Yrs. (1940–45)
Cleveland Westerly, Ohio[3]	0.30	1,210	835,000	417	28.3	42.9	12.1	1,210	5 Yrs. (1941–45)
Duluth, Minn.[4]	0.19	475	336,000	168	28.7	41.6	11.9	1,190	1944
Wyandotte, Mich.[3]	3.15	—	473,000	237	32.8	51.9	17.0	1,700	1 Yr. (1945–46)
New Britain, Conn.[3]	4.55	—	680,000	340	34.8	56.0	19.5	1,950	Summer 1945
Dearborn, Mich.[3]	0.91	—	136,000	68	30.3	51.9	15.7	1,570	Oct., 1945–April, 1946
Neenah-Menasha, Wis.[4]	7.1	—	1,060,000	530	34.0	47.3	16.1	1,610	Jan.–Sept., 1938

[1] Oil at 150,000 B.t.u. per gal.; gas at 650 B.t.u. per cu. ft.
[2] At 10,000 B.t.u. per lb. combustibles.
[3] Multiple hearth type.
[4] Flash drier type.

makes for complexity, both in the design and operation of incineration units.

Supplementary Fuel Requirements

There is an extremely wide variation in operation experience in the amount of supplementary fuel required in sewage sludge incineration. Table VII shows the fuel requirements in ten incineration plants covering a variety of sludge and fuel types. These data are summarized below:

Plant	Type	B.T.U. in Added Fuel per Lb. Cake	B.T.U. in Sludge per Lb. Cake	Per Cent Supplementary Fuel
Detroit, Mich.	B	16	1,990	0.8
Cleveland Southerly	B	143	1,260	11.4
Mpls.-St. Paul, Minn.	B	55	2,030	2.7
Buffalo, N. Y.	A	205	1,750	11.7
Cleveland Westerly	B	417	1,210	34.5
Duluth, Minn.	A	168	1,190	14.1
Wyandotte, Mich.	B	237	1,700	13.9
New Britain, Conn.	B	340	1,950	17.5
Dearborn, Mich.	B	68	1,570	4.3
Neenah-Menasha, Wis.	A	530	1,610	33.0
Average				14.4

The variation in supplementary fuel requirements is from less than 1.0 to 35 per cent, with an average of approximately 15 per cent. While the data are meager and the variation in sludge types great, they indicate a relatively small variation in the supplementary fuel required for the different types of incinerators, the average for the three plants of the flash drying type being 19.6 per cent and for the seven plants of the multiple hearth type being 12.2 per cent.

There is, however, a definite indication in the supplementary requirements of raw sludge as compared to digested sludge. Of the plants which can definitely be classified into either of the two types, Detroit and Minneapolis-St. Paul, which incinerate raw sludge, required only 1.75 per cent additional B.t.u. in the form of fuel, whereas Cleveland Southerly, Buffalo, Cleveland Westerly and Duluth, which handle digested sludge, required 17.9 per cent or ten times as much. As an indication of the effect of such varia-

tion, a plant which handles 100 tons of cake solids of average characteristics per day would require about 3,000,000 B.t.u. of supplementary fuel per day for every 1 per cent difference in fuel requirements. This is equivalent to 20 gal. of fuel oil per day. The use, on the basis of 1.75 per cent of supplementary fuel for raw sludge and 17.9 per cent for digested sludge, would be 35 and 358 gal. per day. At $0.04 per gal. this represents a difference of $12.80 per day or $0.42 per dry ton. In the case of digested sludge, sludge gas is available, but this of course must be considered to be of some value for other uses.

The combustion of sewage sludge and the amount of supplementary fuel required can be considered by another and perhaps more basic method. Since the primary task is moisture evaporation, a yardstick which takes into account the total full additions (in the sludge and in the supplementary fuel) per unit of moisture evaporated will best indicate the combustion problem. Data on the ten plants referred to in Table VII are presented on this basis in the following tabulation:

Plant	Total B.T.U. in Sludge and Fuel per Pound		B.T.U. in Supplementary Fuel per Pound of Water Evaporated
	Cake	Water Evaporated	
Detroit	2,006	2,710	23
Cleveland Southerly	1,403	1,945	199
Minneapolis-St. Paul	2,085	3,150	83
Buffalo	1,955	3,100	326
Cleveland Westerly	1,627	2,270	582
Duluth	1,358	1,905	236
Wyandotte	1,937	2,880	333
New Britain	2,290	3,510	522
Dearborn	1,638	2,350	98
Neenah-Menasha	2,140	3,240	804

The supplementary fuel requirements vary from 23 to 804 B.t.u. per lb. of water evaporated. Of course this alone is not a measure of plant efficiency, since the B.t.u. in the sludge must be given consideration. Considering the total B.t.u. in cake and supplementary fuel the table shows a variation from 1,905 to 3,510 per pound of water evaporated. If one starts from the fundamental fact that a minimum of approximately 2,000 B.t.u. are required in combustion per pound of water evaporated, the excess B.t.u. over this amount can be explained by such factors as excess air used for cooling purposes, the fact that in such plants as Detroit and Minneapolis-St. Paul an excess of heat is present, and by the fuel oil requirements for heating up, cooling down and holding furnace temperatures when not in service. The mere fact that the Detroit and Minneapolis-St. Paul plants utilize 2,700 or more B.t.u. per pound of water does not indicate low thermal efficiency, since excess heat is present and practically no fuel is required for incineration. Duluth and Cleveland Southerly have low heat requirements (1,900 to 2,300) but utilize considerable supplementary fuel because the necessary heat for evaporation is not present in the sludge. This method of comparison permits of a close scrutiny of sludge combustion and supplementary fuel requirements.

In addition to the reasons already indicated there are several others which explain the variation in fuel requirements. The relative numbers of incinerator hours as against standby hours affect the fuel requirements. In plants which incinerate only a few hours daily the use of considerably more fuel is likely than in large plants with a multiplicity of units operating on a 24-hr., 365-day basis.

In general, theoretical calculations confirmed by the results of operation indicate that:

(1) Raw plain settled sludge can be incinerated without supplementary fuel. In fact, an excess of heat is usually available.

TABLE VIII.—Power Requirements for Incineration

Plant	Tons of Cake Annually	Tons of Dry Solids Annually	Power—Kw. Hr. per Dry Ton	Period
Cleveland Southerly, Ohio[2]	43,433	12,420	52.5[1]	1941
	50,217	14,091	43.2[1]	1942
	60,427	17,673	24.3[1]	1943
	50,462	14,179	29.0[1]	1944
Minneapolis-St. Paul, Minn.[2]	112,855	37,091	17.0	1940
	108,912	35,993	14.0	1941
	99,654	33,838	8.8	1942
	96,830	32,955	4.7	1943
	101,980	33,758	6.7	1944
	104,046	34,727	10.2	5 Yrs. (1940–44)
Duluth, Minn.[3]	1,780	585	73.0	1941
	1,870	536	71.0	1944
Dearborn, Mich.[2]	11,502	3,953	13.8	2 Yrs. (1935–36)
Neenah-Menasha, Wis.[3]	6,400	2,160	66.5	Jan.–Sept., 1938

[1] Actual power cost converted to kw. hr. at estimated rate of 1.5 cents per kw. hr.
[2] Multiple hearth type. [3] Flash drier type.

(2) Raw activated sludge incineration requires supplementary fuel.
(3) Digested sludge may or may not require supplementary fuel, depending on the degree of digestion and the moisture content of the cake.

Power Requirements for Incineration

An element of cost of incineration which affects both the construction and operation costs is the power required to operate the various driving units. Table VIII shows the power requirements of five installations. This information may be summarized as follows:

Plant	Type	Kw. Hr. per Dry Ton
Cleveland Southerly, Ohio	B	36.7
Mpls.-St. Paul, Minn.	B	10.2
Duluth, Minn.	A	72.0
Dearborn, Mich.	B	13.8
Neenah-Menasha, Wis.	A	66.5
Average type A (flash drier)		69.2
Average type B (multiple hearth)		20.2

While this information is extremely meager from which to draw broad conclusions, it would indicate a difference in costs from $0.40 to $1.00 per dry ton for the two types, depending on the power rates.

The marked difference in the two types in this connection is perhaps best illustrated in the connected horsepower requirements. The two plants in Minnesota employing incineration permit an interesting comparison in this regard, as follows:

	Duluth	Mpls.-St. Paul
Capacity (tons dry solids daily)	12.8	180
Type	A	B
Number of units	1	3
Total number of motors, per unit	13	6
Connected horsepower per unit	80.83	60
Connected horsepower per ton of dry solids	6.3	1
Actual power use per ton of dry solids (kw. hr.)	72.0	10.2

Some Incineration Problems

In the determination of the broad question of whether to use incineration or other methods of sludge disposal, a number of factors must be considered among which may be mentioned the size of the community, commodity and labor costs, climate as affecting air drying on sand beds, area of site and location with respect to proximity to dwellings, etc. Once having arrived at

a decision to incinerate, a number of other questions must be considered in arriving at a proper decision for a particular situation. Among these the following come to mind:

(*a*) *To Digest or Not to Digest.* This, of course, is a broad question subject to considerable divergence in opinion. It is a fact that the inclusion of digestion results in greater uniformity in both quantity and quality of the sludge to be incinerated. In small plants this is likely to be a factor of some consequence, becoming less important in larger plants. However, the decision on this question affects the question of vacuum filtration both adversely and favorably. The question is a broad one concerning which much more could be written than this paper permits. There is one observation in connection with raw sludge cake characteristics which is sometimes not recognized and which may bear mentioning. This is the fact that even though a large variation occurs in volatile content of the dry sewage solids in raw sludge, the per cent of moisture in the sludge cake in large measure varies almost directly therewith, resulting in a more or less uniform percentage of volatile solids in the sludge cake. As an illustration of this the following table shown at top of right column covers pertinent information from the Minneapolis-St. Paul plant for the year 1943.

Month	Solids in Cake (%)	Volatile in Dry Solids (%)	Volatile Solids in Cake (%)
Jan.	34.4	60.7	20.9
Feb.	35.8	58.0	20.8
March	35.9	56.8	20.4
April	34.7	58.4	20.3
May	36.6	54.3	19.8
June	34.6	59.0	20.4
July	33.2	63.0	20.9
Aug.	32.6	64.0	20.9
Sept.	31.3	66.6	20.9
Oct.	30.6	68.8	21.0
Nov.	29.8	70.7	21.0
Dec.	29.7	71.9	21.3
Ave.	33.4	61.3	20.5
Min. volatile (May 7)	45.6	31.5	14.4
Max. volatile (Dec. 25)	28.6	73.9	21.2

As compared with an average for the year of 20.5 per cent volatiles in the cake, the volatile for the minimum month (May) was 19.8 per cent and for the maximum month (December) 21.3 per cent. Even on the day of maximum volatile content (December 25) the content of volatile solids in the cake was only 21.2 per cent. This feature of raw sludge filtration of automatically increasing the moisture content of cake of high volatile solids results in securing a somewhat uniform cake quality as far as incineration is concerned. Apparently (Table VII) this same thing is experienced at Detroit where the average content of volatile solids in the cake is 19.9 per cent. The volatile solids (in the cake) at four plants filtering digested sludge were only 13.5 per cent.

(*b*) *To Filter or Not to Filter.* In view of the fact that ordinarily the preparatory process—vacuum filtration—costs two or more times as much as the final process—incineration—it has appeared to the writer that if a process of concentrating liquid raw sludge to perhaps 85 per cent moisture content could be developed, incineration of liquid sludge might be economical. In 1935 the writer made an investigation of this possibility in connection with the Minneapolis-St. Paul project, the results of which are sum-

marized below:

Moisture in Cake (%)	Total Annual Charges per Dry Ton ($)		
	Filtration	Incineration	Total
60	5.60	0.70	6.30
65	4.50	1.00	5.50
70	3.80	1.40	5.20
75	3.30	2.20	5.50
80	2.50	3.40	5.90
85	—	6.50	6.50
90	—	10.30	10.30

The increase in estimated cost of incineration with increasing moisture content in the cake or liquid sludge is principally due to greater fuel oil requirements. While the total costs are the lowest in the range of usual cake moisture content (65 to 75 per cent) the additional cost in the case of liquid sludge of 85 per cent moisture content is not sufficiently great to rule out the possibility of development in the case of liquid sludge incineration, particularly when the saving in first cost is borne in mind.

In fact, two small plants in Ohio have been incinerating liquid sludge for four or more years (38). The operation and maintenance costs at Ashland, Ohio (41), are stated to be $8.63 per dry ton for sludge of 88 per cent moisture. In the same article the costs at Piqua, Ohio, are given as $7.50 per dry ton for sludge of 88 per cent moisture. If these costs include all elements of direct and indirect charges, they would indicate a possibility in this direction, since as quoted they are less than the costs of vacuum filtration and incineration at two large plants referred to in Table V, wherein the costs were $10.56 and $11.26 per dry ton.

(*c*) *To Recover Heat.* In at least two plants (Minneapolis-St. Paul and Detroit), with incinerators of the multiple hearth type, investigations have been made or are under way to recover some of the surplus heat generated in the combustion of raw primary sludge. Referring to the Minneapolis-St. Paul plant the writer, in a paper (44) presented in 1942 before the Sanitary Engineering Division of the A.S.C.E., pointed out that "various methods have been developed which indicate the possibility of generating sufficient steam for all heating purposes and electric power requirements." The impossibility of securing materials during the war prevented the development of this project. At present the only utilization made of excess heat is in the use of the hot air from the central shaft for heating one large building. Because of the present excess of heat, large quantities of combustion air, and water admitted through sprays, are required for cooling.

At the Detroit plant, Garrity (34) states that plans are in preparation for heat recovery units which will furnish 1,000 kw. or 60 per cent of the energy required to operate the entire plant. He points out that the potential heat recovery is about 23 per cent of the total heat in the sludge.

(*d*) *Thermal Efficiency vs Simplicity.* While the inclusion of elaborate equipment to secure high thermal efficiency may be worth consideration in plants burning digested sludge or raw sludge of high moisture content, it is the writer's impression from observations of several incineration plants that in many cases the reduction in simplicity is worth more than the theoretical increase in thermal efficiency. To attain higher efficiencies greater power consumption is generally required, which more than offsets the possible increase in fuel costs with simpler equipment. This statement applies to equipment of both general types. Considering the nature of the problem involved and the nature of the materials dealt with, the more rugged and simple the equipment the greater the dependability and the lower the costs.

The following is offered as an illustration. At the Minneapolis-St. Paul

plant the preheater elements were removed after three years of operation, with the result that power costs, already low, were reduced from 17 kw. hr. to 5 kw. hr. per dry ton, or a saving in power costs of approximately $6,000 annually. Estimated reductions in replacement and maintenance costs brought the total saving to about $12,000 annually, and since the preheaters were perhaps the major source of difficulty and cause of outages in early operation, this increased the dependability of service immeasurably. If additional fuel oil were required because of this reduction in thermal efficiency (which, however, was not the case), the amount which could be purchased with the $12,000 saving annually (300,000 gal. at 4¢) is very large compared to the ordinary usage at this plant of 70,000 gal. annually.

(*e*) *To Combine with Garbage Incineration.* Compared to an approximate average of 0.2 lb. of suspended solids per capita per day in sewage, the average contribution of garbage per capita daily is 0.1 lb. on a dry basis. Several plants are grinding garbage and adding it to the sewage solids, usually in the digestion tanks. In the situation where the combined solids are to be vacuum filtered and incinerated, the additional cost of removing the water from the garbage solids in the mixture, to restore them to their original moisture content so they can be incinerated, is quite high. In fact, the dewatering alone may be several times as expensive as direct incineration of the garbage alone.

There is often a tendency to combine these two municipal functions. If such combination is to occur in a particular community, a logical way is to incinerate the garbage solids directly without grinding and addition to the sewage or sludge. Six of the plants of the multiple hearth type listed in Table I are designed to incinerate a mixture of green garbage and sewage sludge cake. The extent of development in this direction in the future is problematical, but with the increase in the number of sewage sludge incinerators, the possibility of combining may occur to an increasing number of public officials.

(*f*) *To Dry or to Burn.* The advantages of drying to the point of having a fertilizer, or of carrying the process to complete combustion, is a matter concerning which there has been much written and verbal discussion. It is a broad question involving a consideration of first and operating costs, variations in market prices from time to time, the location of the plant with respect to the market, etc. If sludge can be incinerated for $1 to $2 per dry ton, the decision to make a large expenditure in plant and to spend $15 or more per dry ton to make a fertilizer (the value of which may fluctuate from $5 to $30 per ton over the years) is one deserving thorough consideration.

Equipment of both the flash drying and multiple hearth types have been utilized for drying sludge as a fertilizer, the former having been more generally utilized for this purpose. Of the fifteen flash drying plants in the U. S., three are operated as incinerators only, seven as dryers only, and five can be operated either as dryers or incinerators. The multiple hearth type has generally been used for incineration although in at least one plant (Dayton, Ohio) the unit has been used exclusively as a dryer. Apparently both types are capable of separate or double use.

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SEWAGE SLUDGE INCINERATION—A DISCUSSION

By Mark B. Owen

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Prof. Schroepfer's paper is most comprehensive and complete. I would not be telling the truth if I did not admit considerable pride in my connection with what was probably the first successful plant-size sewage sludge incinerator. It is probably trite to say that engineers become more conservative with age. This is well illustrated in my case by Prof. Schroepfer's quotation of my statement made some 14 years ago to the effect that I believed incineration would be the ultimate answer to the sludge problem in all plants. Of course, I would not make that statement today, because quite obviously it is not the ultimate answer; as yet, due to many factors such as cost and operating difficulties, it is not generally applicable to the smaller plants.

It is unfortunate, I believe, that many of the smaller plants equipped with sludge incinerators do not find it economical, practical, nor convenient to operate the incinerators they now have. If the exact number of these plants were known, together with their combined capacities, I think Prof. Schroepfer's figures on the daily tonnage of sewage solids incinerated would have to be scaled down considerably.

I would like to point out for the benefit of incinerator operators something that is fundamental in combustion and that was very well illustrated by the experience at Minneapolis-St. Paul in cutting down the combustion air admitted to the furnaces, with attendant results. The quantity of air admitted to a furnace is an extremely important function of the operation. Every atom of carbon must join with two atoms of oxygen to produce carbon dioxide in complete combustion. They must, of course, combine in an atmosphere of proper temperature. If only one atom of oxygen joins one of carbon, carbon monoxide is produced and one extra carbon atom gets away. When carbon atoms become free in that manner, black smoke is seen emanating from the stack.

Actually the elemental gases involved in combustion are diatomic; that is, two atoms of the element are required to produce the molecule. Hence the chemical equations representing the above reactions would be as follows:

$$(a)\ C + O_2 = CO_2$$
$$(b)\ 2C + O_2 = 2CO.$$

Thus, one molecule of carbon reacts with one molecule of oxygen to form one molecule of carbon dioxide; but when two molecules of carbon react with one molecule of oxygen, two molecules of carbon monoxide are formed.

Since the heat of combustion of carbon burning to carbon dioxide is 14,600 B.t.u. per lb., and the heat of combustion of carbon burning to carbon monoxide is 4,450 B.t.u. per lb., a loss of heat going up the stack of over 10,000 B.t.u. per lb. occurs. The ultimate in combustion would be to admit to the furnace only that quantity of air that would provide the theoretical amount of oxygen needed to burn all the carbon to carbon dioxide. If insufficient air is present, some free carbon will escape, which we recognize as smoke.

Obviously, it would be quite impractical to have such precise control over the quantity of air admitted to the furnace. Infiltration of air due to leakage would always be present to upset the ideal conditions. Practically, therefore, the designers of all types of combustion apparatus allow for some excess air. In the case of oil burners attached to sludge incinerators, 25 per

cent excess air is allowed. For the furnace itself 50 per cent excess air is used. In the case of hand-stoked furnaces, such as garbage incinerators, it is customary to design the structures on the basis of 100 per cent excess air.

The reason for allowing excess air is to be sure that all of the free carbon is burned. On the other hand, excess air contributes directly to the heat lost up the chimney. For example, the specific heat of air may be taken at about 0.24. At 50 per cent excess air there will be about 4 lb. of excess air in 13 lb. of gases going out the chimney. If the gases leave at 1,000° F., the heat lost per pound of combustible would be in the neighborhood of 900 B.t.u. per lb. of combustible. Consequently, when the Minneapolis-St. Paul operators cut down the volume of combustion air, they eliminated this heat loss, which raised the temperature of the combustion gases, but at the same time produced smoke because of insufficient oxygen to burn all of the free carbon.

For a long time I have wanted to write an article regarding the fuel values of sewage sludge and of garbage. The conservatism that comes with the years has held me back. It is too long a subject to cover in this discussion, except to point out the following: The fuel value of sludges in relation to their volatile content is, at best, a rough approximation.

In my opinion an incinerator cannot be properly designed on the basis of the volatile content of the sludge. Sludge should be considered as a fuel and as such ultimate analyses of several composite samples of sludge should be made to determine the carbon, hydrogen, oxygen, nitrogen, and sulfur contents. Lacking this information, the theoretical quantity of air required for combustion cannot be calculated, and it follows that the size of gas passages, flues, and chimneys cannot be intelligently determined.

Besides the ultimate analysis, the calorific value must be determined. With some exceptions, it is possible to apply DuLong's formula for determining the B.t.u. value of sludge as it is frequently applied to coal. In passing, it may be well to mention that too little attention is given the heat release of sludge when it is burned, in terms of B.t.u. per cu. ft. of firing chamber per hour. This, quite likely, holds part of the answer to why rabble arms and rabble teeth need occasional replacement, as mentioned by Prof. Schroepfer.

If the designer thinks only in terms of the ultimate analysis of the sludge, he will not be greatly concerned about whether the sludge is raw, activated, chemically precipitated or digested. Moreover, one can then intelligently study and compare fuel consumption in various plants.

It will be understood that there are many other factors, entering into the incineration problem, such as the water and ash content of the sludge and the fixed heat losses inherent in the incinerator itself. All of these factors must be considered in preparing the heat balance.

With two or three exceptions, all sludge incinerators burn solids dewatered on vacuum filters. It is my opinion that the most important part of sludge incineration is the operation of the vacuum filters. I believe most of the success of the operation of the first incinerator at Dearborn was due to the experience of the plant personnel in operating the vacuum filters. It may be recalled that the filters operated two years before the incinerator was installed. By that time the operators were so familiar with sludge dewatering that they could, within practical limits, produce a thin or a thick cake, a dry or a wet cake, and in so doing were quite successful in almost completely controlling combustion in the incinerator.

I believe it is a mistake to design and install a sludge incinerator in a plant that has not been in operation

at least six months. Preferably, I think one should wait until the plant has been in operation at least a year. If one allows a lapse of time of six months or a year, it provides the operators an opportunity to become familiar with vacuum filter operation and to overcome many of the headaches that are always present in starting up a new plant.

Equally important is the fact that at the end of six months, the sewage and sludge produced have become what one might term normal for that plant. It is then possible to determine the exact characteristics of the so-called normal sludge and design incinerator facilities based on known, rather than assumed data. The writer's firm has adopted this policy in so far as sludge incineration is concerned.

Prof. Schroepfer's paper points out the rather high cost of sludge dewatering as compared to the cost of incineration. I think the incineration of liquid sludge should be given more study. Where incineration seems to be the answer to sludge disposal, some type of thickener should be developed that would produce a sludge of 12 to 20 per cent solids. When that time comes, my 1932 statement that incineration is the answer in all plants may become true.

I have already gone on record regarding the desirability of combining garbage with sludge in the smaller installations. I think too little advantage has been taken of this idea. It can be an economical and sanitary method of disposing of two very annoying municipal wastes.

PHOSPHATES IN SEWAGE AND SLUDGE TREATMENT. IV. EFFECT OF DEWATERING OF SLUDGE *

By Willem Rudolfs and Lloyd L. Falk

Chief and Research Associate, Respectively, Rutgers University, New Brunswick, N. J.

Phosphates are a normal constituent of domestic sewage solids. Practically all organic industrial wastes contain phosphorus, but particularly those wastes produced by the fermentation industries. The solids in some of these wastes contain considerably larger quantities of phosphates than does domestic sewage sludge as may be seen from the following comparison of analyses made in our laboratory:

Waste	P_2O_5 in Dry Solids (%)
Distillery	2.7 – 3.5
Yeast	4.0 – 7.1
Brewery	1.4 – 2.6
Penicillin	6.9 –12.5
Streptomycin	1.1 – 5.0
Fresh sewage solids	0.9 – 2.1
Ripe sludge	1.25– 2.76

The particular wastes mentioned above produce relatively large volumes of sludge when treated with chemicals, and the sludges are difficult to dewater.

It has been shown previously (1) that even small quantities of phosphates added to sewage may cause an appreciable increase in sludge volumes, and that the lime requirement for clarification of sewage varies with the P_2O_5 content of the sewage. It may be expected, therefore, that addition of fermentation wastes as well as other wastes containing more phosphates than sewage would affect the sedimentation and sludge volumes of the mixtures.

Further studies on the effect of various types and different quantities of phosphorus compounds on the dewatering of fresh solids and ripe sludge are presented in this paper, together with an explanation of the increases in sludge volumes and the retardation of dewatering.

Methods and Materials

To determine the drainability of various sludges with and without additions of different phosphorus compounds, fresh solids and ripe sludges were used. Some of the sludges were treated with ferric chloride or ferric chloride and lime after the addition of the phosphorus compounds; others were dialysed and treated with chemicals. In general, the sludges were suction filtered through Buchner funnels, the volumes of filtrate and the pH were determined, and the moisture content of the cakes was measured. More specific details and procedures are described in conjunction with the results recorded concerning different groups of experiments.

Effect on Filtration Time

In order to establish a basis for comparison, determinations were made of the length of time required before cracking took place of the cake formed from a given volume of sludge subjected to a specific pressure. On the same specimens the percentages of moisture in the cakes were determined after the pressure had been reduced to a definite level. The pH values of the filtrates were also determined. The same procedure was repeated with sludge treated with different quantities of ferric chloride.

As an example of the results ob-

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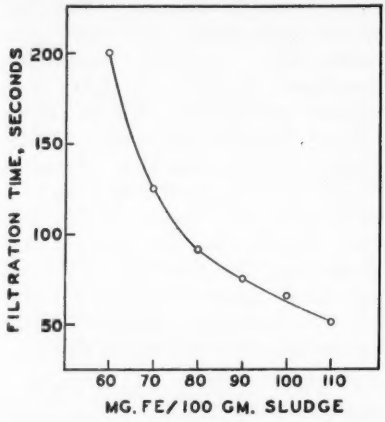

FIGURE 1.—Filtering time of ripe sludge required with increasing quantities of ferric chloride.

tained, the filtration time required for ripe sludge with an initial solids concentration of 5.83 per cent and treated with increasing quantities of ferric chloride is shown in Figure 1. The results show that the filtration time required was reduced from 174 seconds with 60 mg. Fe per 100 grams of sludge to 50 seconds when 110 mg. Fe was used. To portions of the same batch of sludge were then added phosphorus compounds in increasing quantities prior to treatment with $FeCl_3$. As an example of the results obtained, the filtration time required when the sludge received increasing amounts of ammonium phosphate prior to treatment with 100 mg. Fe per 100 grams of sludge is shown graphically in Figure 2, Curve A.

Whereas the ripe sludge treated with $FeCl_3$ alone required about 40 seconds before cracking of the cake occurred, it took 2.5 times as long when 20 mg. P was added and 24 times as long when 100 mg. P was added in the form of ammonium phosphate. The pH values of the filtrate changed only slightly, from 6.5 for the iron salt treated sludge to 6.9 for the sludge to which the highest amount of phosphate was added. The amount of filtrate obtained up to the time of cracking was slightly higher with increasing amounts of phosphate, and the moisture in the cake was slightly lower.

In an effort to determine whether the ammonium phosphate interfered with the filtration time, solely because the ferric chloride was utilized for the precipitation of the phosphorus, or whether the phosphate also affected filtration because of its stabilization effect on the pH of the liquor, batches of ripe sludge were first treated with ferric chloride and then with ammonium phosphate. The results of such a trial are shown in Figure 2, Curve B. It appeared that the filtration time required for the lower quantities of phosphate was the same whether additions of the phosphorus compound were made before or after $FeCl_3$ treatment, whereas with higher quantities, the time was reduced, although the time required with 100 mg.

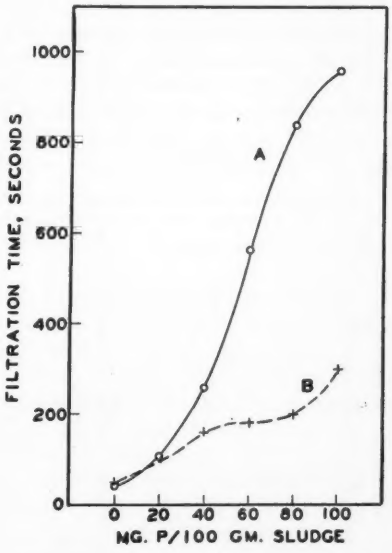

FIGURE 2.—Filtering time of ripe sludge required with increasing amounts of ammonia phosphate added and constant amounts of $FeCl_3$. Curve A represents phosphate added before and Curve B represents phosphate addition after $FeCl_3$ treatment.

P was still 6 times as long as without P addition. This led to the belief that a phosphorus compound which stabilizes or increases the pH value of the sludge liquor affects the dewatering, in addition to any effect the phosphate may have on the ultimate water-holding capacity of the sludge through the formation of a jelly-like precipitate or otherwise. If this assumption is correct, the effect of various phosphorus compounds added in the same amounts should affect the dewatering or filtering time to a different degree, because of the difference in stabilization or buffer action of the various phosphorus compounds.

Effect of Various Phosphorus Compounds

Ripe Sludge

To ripe sludge, containing 5.83 per cent total solids and requiring a filtering time of approximately 40 minutes, various quantities of different types of phosphorus compounds were added and the whole was then treated with $FeCl_3$ to obtain optimum dewatering time. The optimum amount of ferric chloride required was approximately 1.7 per cent Fe on a dry matter basis. The optimum dewatering time varied from 1.1 to 1.3 minutes. The phosphorus compounds used were phosphoric acid, H_3PO_4; monocalcium phosphate, $Ca(H_2PO_4)_2 \cdot H_2O$; diammonium phosphate $(NH_4)_2\ HPO_4$; sodium hexametaphosphate, $NaPO_3$ (calgon); and disodium phosphate, Na_2HPO_4. The results of a series of experiments are shown in Figure 3, where the filtration time, the pH of the filtrate, and the moisture in the cake are plotted against increasing quantities of phosphate compound added. The results show in general that:

1. With increasing quantities of phosphorus compounds, filtration time increases.
2. Different types of phosphates have varying effects.
3. Relatively small changes of pH values are not directly related to filtration time.
4. With increasing amounts of phosphorus compounds, there is a definite tendency to decreasing moisture contents of the cake produced.
5. The longer the filtration time, the lower the moisture content in the cake.

The various curves in Figure 3 seem to indicate that when the pH of the liquor decreases, the filtration time is

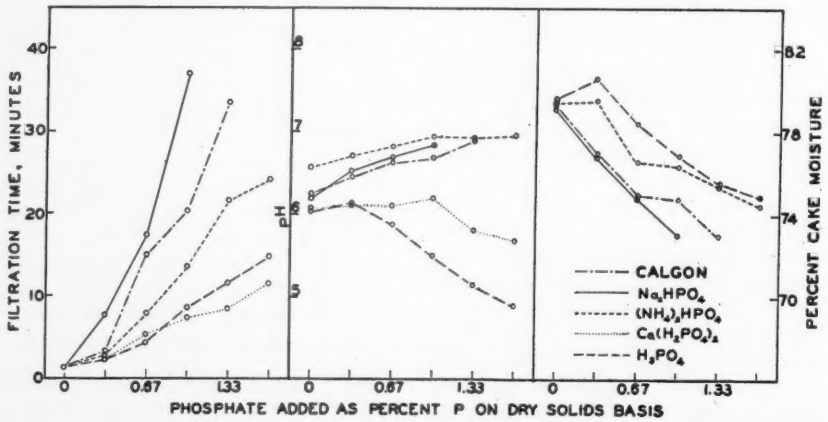

FIGURE 3.—Filtering time, pH and moisture changes in relation to various quantities of different types of phosphates added to ripe sludge. Sludge treated with $FeCl_3$ (1.7 per cent Fe on dry solids basis).

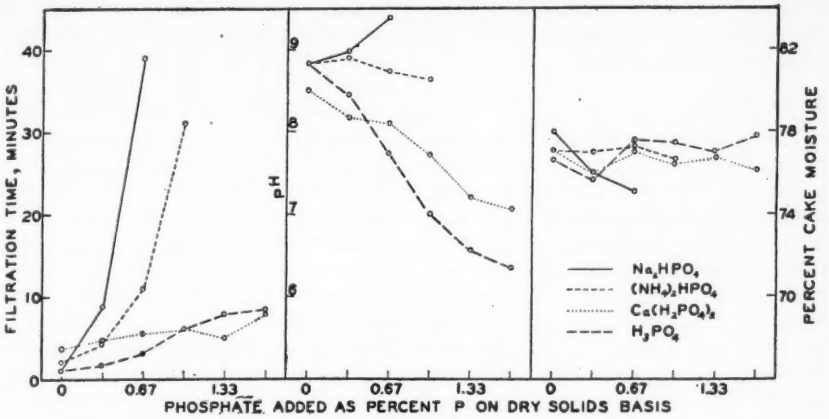

FIGURE 4.—Effect of phosphates after conditioning of ripe sludge with lime and ferric chloride.

increased to a lesser extent, and that the ultimate moisture in the cake remains somewhat higher than when the pH values in the liquor increase. The question arises whether similar results would be obtained if the pH of the sludge was raised by adding lime as well as ferric chloride, which constitutes the practice at many plants.

To portions of the same batches of ripe sludge, previously used, various quantities of different types of phosphorus compounds were added and the sludge was treated with ferric chloride (1 per cent Fe) and lime (8.6 per cent on a dry solids basis). The results of one series are presented graphically in Figure 4. It is evident from the results that the effect of phosphorus compounds on the filtration of ripe sludge, after conditioning with lime and ferric chloride, was similar to the effect when ferric chloride alone was used prior to the phosphate additions. Any difference noticed was in filtration time. The sodium and ammonium phosphates had a more pronounced effect, whereas the phosphoric acid and calcium phosphate exerted a somewhat less marked effect in the presence of lime. It appears that raising the pH value to a supposed optimum did not ameliorate the effect of the phosphorus compounds used.

When the sludge was conditioned with ferric chloride alone before phosphate additions, there was a decided tendency for the moisture content in the cake to decrease with increasing amounts of phosphate. Conditioning with lime and ferric chloride before addition of phosphates did not show this tendency, the moisture content of the cakes produced was fairly constant for all phosphates, and increasing amounts did not change the results.

In general, it appears that the effect of phosphates is more pronounced when ferric chloride is used as the conditioning agent and that the effect is still greater when lime and ferric chloride are used, as compared with untreated ripe sludge. It seems that those phosphates which stabilized or increased the pH values to the greatest extent caused the greatest increase in filtering time. The hypothesis that by keeping the iron in solution, *i.e.*, decreasing the pH value, the filtering time increases, does not seem to hold. It would seem that a phosphate which stabilizes or increases the pH forms a greater amount of voluminous precipitate with high water holding capacity,

which in turn retards filtration. Any precipitate formed would cause increases in sludge volume.

Fresh Solids

The percentage phosphorus present in dry fresh solids is usually less than in dry ripe sludge. Part of the phosphorus compounds in fresh solids may be present in a different form from that in ripe sludge, although the percentages of insoluble and of available P_2O_5 are about the same in fresh solids as in ripe sludge. If the presence of phosphates induces the sludge to hold its water more tenaciously, and if a precipitate formed by the addition of phosphorus compounds causes an increase in sludge volume as well as an increase in the water holding capacity, the effect of phosphates on fresh solids should be similar to the effect on ripe sludge.

Fresh solids containing 5.09 per cent total solids were used in a series of experiments with additions of various phosphates in different quantities. The fresh solids were treated with ferric chloride (1.4 per cent Fe on a dry matter basis) before the phosphates were added. The results of a series of such experiments are illustrated in Figure 5. The filtration time increased with increasing amounts of phosphates, and the sodium phosphate again caused the greatest effect, followed by ammonium phosphate, calcium phosphate and phosphoric acid. The moisture content of the cakes decreased with the increasing amounts of phosphates. In general, the effect of the phosphates on fresh solids conditioned with ferric chloride was similar to the effect on ripe sludge.

Another series of experiments were conducted in which the fresh solids were treated with lime (9.8 per cent on a dry solids basis) and ferric chloride (1.4 per cent Fe) before additions of phosphates. The results shown in Figure 6 indicate materially less effect on the filtration time than when ferric chloride alone was used as conditioning agent. Sodium phosphate, again, exerted the greatest influence on the filtration time. The other phosphates used had relatively insignificant effects. It can be seen that the effect was independent of the pH values; with sodium phosphate the pH remained fairly constant with increasing dewatering time, whereas the pH values of the sludges to which the other phosphates were added decreased in varying degrees without material difference in filtration time. None of

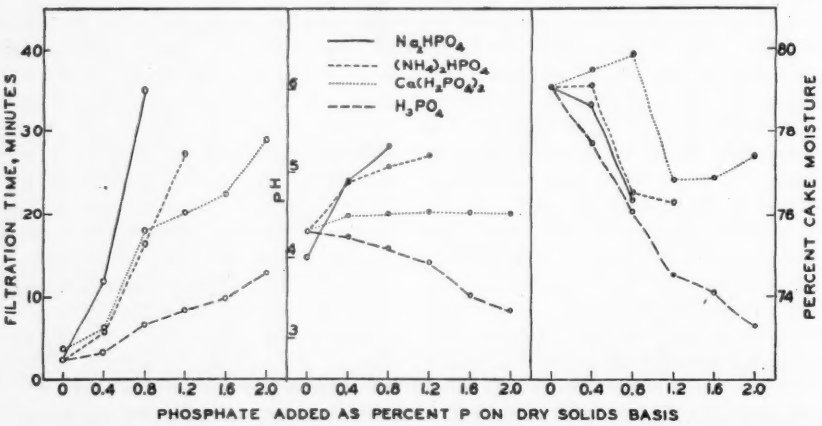

FIGURE 5.—Effect of phosphates on dewatering of fresh solids conditioned with ferric chloride.

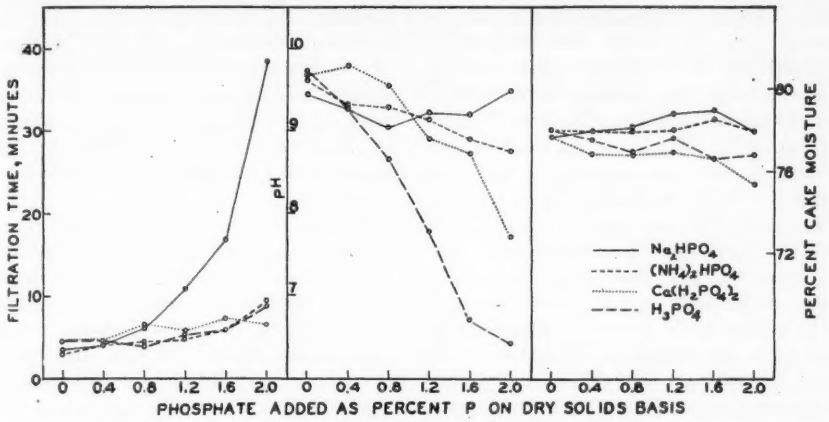

FIGURE 6.—Effect of phosphates on dewatering of fresh solids conditioned with lime and ferric chloride.

the phosphates added in various quantities caused a pronounced effect on the moisture content of the cake.

Supernatant Liquor

The effects of phosphates on the clarification, settleability and sludge volume of supernatant digester liquor were studied by the addition of varying amounts of different phosphates alone and in conjunction with ferric chloride and lime to the liquor.

The materials were flash-mixed and the clarification and sludge volume determined after one hour's settling. The effect of typical phosphates on clarification of supernatant liquor is indicated in Table I. Addition of various amounts of phosphates added caused a reduction in clarification. The effect of 50 p.p.m. phosphorus was practically the same as that of 5 times that amount. It is estimated that the original digester liquor contained about 300 p.p.m. phosphorus, so that the addition of 50 p.p.m. was relatively small.

Phosphoric acid, which caused a progressive lowering of the pH values with increasing amounts, appeared to have the least effect on clarification, whereas sodium phosphate, with practically no effect on the pH values of the liquor, appeared to have the greatest effect on clarification.

Of interest is the markedly increased

TABLE I.—Effect of Phosphates on Clarification of Supernatant Digester Liquor (Suspended Solids Remaining in Settled Liquor; Percentage Ash of Suspended Solids)

Phosphates Added (p.p.m.)	H_3PO_4			$(NH_4)_2PO_4$			Na_2HPO_4		
	Susp. Sol. (p.p.m.)	Ash (%)	pH	Susp. Sol. (p.p.m.)	Ash (%)	pH	Susp. Sol. (p.p.m.)	Ash (%)	pH
0	240	22	7.2	188	24	7.4	144	24	7.4
50	284	28	7.0	336	27	7.4	476	51	7.4
100	284	28	6.8	396	42	7.3	404	59	7.3
150	284	29	6.7	382	46	7.3	420	57	7.3
200	282	29	6.6	424	52	7.3	360	57	7.4
250	278	36	6.5	360	54	7.3	376	62	7.4

ash content of the suspended solids remaining in the liquor. In the case of phosphoric acid addition, the percentage ash in the suspended solids remaining in the liquor increased somewhat with 50 p.p.m. addition of P, whereas the ash content of the suspended solids remaining in the liquor doubled with the same quantity of P in the form of sodium phosphate. The increase in ash content appears to be due principally to the precipitation of the phosphates; however, additions of greater quantities of phosphates did not cause proportional increases in the suspended solids remaining, or proportional increases in the ash content of the suspended solids. The phosphates added in excess of 50 p.p.m. were apparently nearly all precipitated and settled out as sludge.

If this assumption is correct, the quantities of sludge formed should increase in relation to the extent of precipitation of the phosphorus compounds. Addition of ferric chloride and lime would aid in the precipitation of the phosphates, and the volume of sludge produced should increase roughly in proportion to the amounts of conditioning agent added, the increase being limited by the phosphate content.

In order to determine whether these suppositions were correct, a series of experiments were run in which were added different phosphates alone, phosphates and ferric chloride, and phosphates, ferric chloride and lime, to equal quantities of supernatant liquor. Some results obtained on sludge volumes and pH values are shown in Figure 7. The volume of sludge produced increased to the greatest extent with increasing amounts of sodium phosphate. Additions of ferric chloride caused greater sludge volumes than did phosphates alone, and with ferric chloride and lime the sludge volumes were still greater.

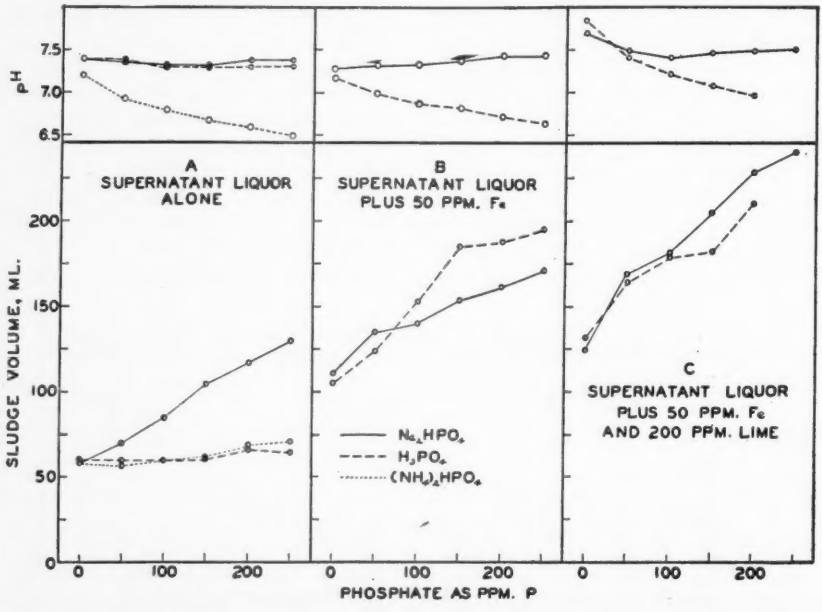

FIGURE 7.—Effect of phosphates and coagulating agents on the volume of sludge produced from supernatant digester liquor.

TABLE II.—Precipitation of Phosphates by Ferric Chloride (Sludge in Per Cent of Original Volume)

P (p.p.m.)	H_3PO_4		$Ca(H_2PO_4)_2$		$(NH_4)_2HPO_4$		$NaPO_3$		Na_2HPO_4	
	Sludge	pH	Sludge	pH	Sludge	pH	Sludge	pH	Sludge	pH
0	0	2.3	0	2.3	0	2.3	0	2.3	0	2.3
20	0	2.0	0	2.1	T	2.2	T	2.4	T	2.2
40	0	1.8	0	1.9	T	2.2	6	2.3	82	2.3
60	0	1.7	T	1.8	52	2.3	38	2.3	82	3.1
80	0	1.7	T	1.8	98	2.4	84	2.2	88	5.7
100	0	1.7	12	1.8	82	3.1	84	2.2	88	6.3

T = turbid.

When the increases in sludge volume caused by the conditioning agents are subtracted from the total amounts of sludge, it is apparent that the sodium phosphate exerted an effect independent of the conditioning agents, whereas the ammonium phosphate and phosphoric acids were precipitated by the conditioning agents, resulting in increasing quantities of sludge.

In an attempt to determine the effect of phosphates in the presence of ferric chloride on sludge volumes, phosphate solutions in distilled water were treated with ferric chloride, flash-mixed and allowed to settle for one hour. The amounts of settled precipitate, the conditions of the supernatant, and the pH values were determined. The data in Table II are arranged in the order of increasing effects on sludge formation.

It is not implied that the same reactions occur in sludges when conditioned with ferric chloride, because there are other substances in the sludge which would react directly or indirectly with the phosphates or iron chloride, but it is believed that the results are sufficiently similar to show trends. The phosphates which show the greatest precipitation have the greatest effect on clarification. They have also the greatest retarding action on filtration, and produce the largest volumes of sludge.

The precipitates of iron phosphates formed were light and voluminous, settled slowly and caused increasing volumes of sludge. This voluminousness means greater absorption of water and may explain the greater time required to vacuum-filter ripe sludge and fresh solids. All results seemed to indicate that the sodium phosphate had a greater effect than the calcium and ammonium phosphates or the phosphoric acid. The question arises, therefore, whether the sodium or the phosphate ions were mainly responsible.

Effect of Sodium and Phosphates

Fresh solids with a concentration of 5.6 per cent dry matter were treated with varying amounts of sodium hydroxide and trisodium phosphate. The chemicals were applied in the usual manner and the amounts of filtrate produced in 5 minutes for one series of experiments are plotted in Figure 8. The amounts of filtrate which could be removed were small. The NaOH aided dewatering slightly, with the Na_3PO_4 lagging, causing a slight increase in dewatering when very large quantities of chemicals were added.

The supernatant liquors of the sludges treated with sodium hydroxide and sodium phosphate were highly charged with suspended material, the amounts increasing with increasing quantities of the salt. Efforts to remove the suspended material by centrifuging failed.

Similar series of dewatering experiments were made with additions of

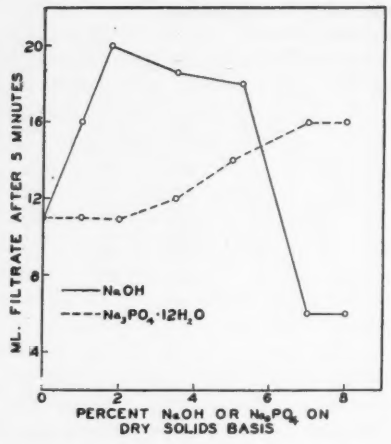

FIGURE 8.—Effect of NaOH and $Na_3PO_4 \cdot 12H_2O$ on dewatering of fresh solids.

ferric chloride and with additions of 5.35 per cent trisodium phosphate before ferric chloride was applied. The percentage of total water removed after 3 minutes for one series is illustrated in Figure 9. Preliminary work showed that apparently very good coagulation took place with the different types of sludges used. Observation of the series of experiments illustrated in Figure 9 indicated that excellent coagulation took place, but the addition of sodium phosphate impeded filtration. The ratio of trisodium phosphate to ferric chloride added was kept relatively low to prevent precipitation of ferric phosphate. In all instances, the sodium phosphate was added first.

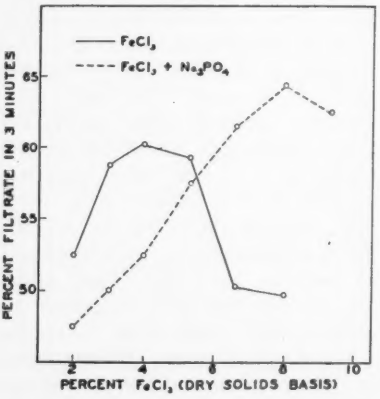

FIGURE 9.—Comparison of varying amounts of $FeCl_3$ and $Na_3PO_4 \cdot 12H_2O$ + $FeCl_3$ on dewatering of fresh solids.

Examination of the pH values of the liquor showed that best filtration of the sludge treated with ferric chloride alone was obtained at a pH of 4.2 and with sodium phosphate additions at about 4.5. In order to remove a slightly higher percentage of water from the sludge the amounts of ferric chloride had to be doubled when trisodium phosphate was added. The lowest moisture content of the cake obtained with ferric chloride addition alone was 71 per cent and with ferric chloride in conjunction with trisodium phosphate 70 per cent.

A series of experiments to determine the possible effect of mixing and stirring, as well as using phosphates with lower sodium content, showed no significant differences from those illustrated. Various phosphates were also tried in conjunction with ferrous salts, but the effects of the phosphates were the same.

The results, in general, demonstrated that in the absence of an iron conditioning agent, relatively large quantities of sodium hydroxide caused a reduction in dewatering, but that the effect of trisodium phosphate was more pronounced. When an iron conditioning agent was used, increasing quantities were required to obtain equivalent results with phosphates added. The removal of liquid from the sludge was impeded. It appears that the trivalent phosphate ion is absorbed by the weakly charged negative sludge particles causing a dispersion of the sludge particles, and decreasing the reaction with the positively charged trivalent ferric ion. If any formation of less soluble ferric phospho-compounds occurs, it does not improve filtration. A solution link may possibly be formed

by the absorption of the phosphate ion and the reaction with ferric compounds may be aided, but this does not increase the rate of dewatering. In this respect it is of interest that the filtrate of the sludge treated with phosphate-ferric chloride was uniformly very clear. This may indicate that the phosphate aids hydrolysis of the ferric chloride, with removal of finely divided sludge particles or precipitation of the non-reacting iron by the phosphate. Raising the pH value of coagulation by adding a phosphate buffer results in higher iron requirements.

Effect of Removal of Ions

Fresh domestic sewage sludge contains considerable quantities of substances having a gelatinous structure, resulting in a pronounced protective colloidal effect. On the assumption that all organic nitrogen present in fresh solids is in the form of proteins, the protein concentration is high (16 to 20 per cent), and the fat content may vary from 20 to 30 per cent of the total dry material. In contrast, the concentration of electrolytes and salts is low, the inorganic constituents existing chiefly as mineral aggregates such as would be found in finely divided or occluded grit and clay. With the exception of phosphates and chlorides, the salts are derived mostly from the water supply, and the concentrations present approach those in the water supply.

In studying the colloidal behavior of sludges in relation to dewatering, we are mainly interested in (1) the adsorbed negative ions which impart a negative charge, and (2) protective colloids which abort efforts to precipitate or coagulate by means of small amounts of electrolytes or positively charged hydrosols. In filtration of sludge, we are dealing with coagulation of the more finely divided material and the shrinking, accompanied by dehydration, of the larger gel structure. In respect to the effect of phosphates on dewatering, we are interested in removing the salts present to determine the colloidal behavior with and without additions of electrolytes.

To determine the effect of removing electrolytes, fresh solids were subjected to electrolysis with and without a membrane. The filtration curves obtained before and after direct elec-

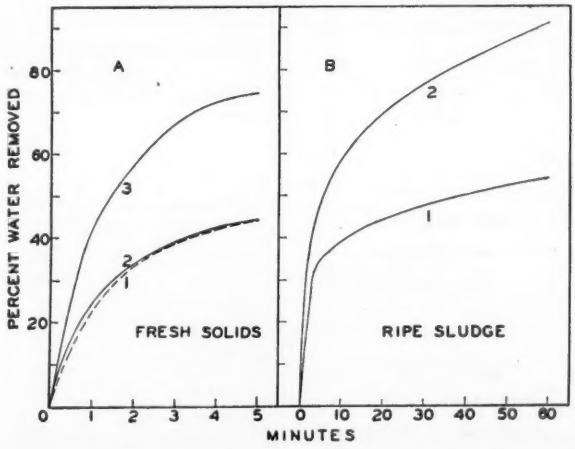

FIGURE 10.—(A) Effect of electrodialysis on dewatering of fresh solids: (1)—electrolysis without a membrane; (2)—before electrolysis; (3)—electrodes separated by a membrane. (B) Ripe sludges: (1)—filtration before dialysis; (2)—after electrodialysis.

trolysis practically coincide (Figure 10A), whereas under the same conditions, but with the electrodes separated by a semipermeable membrane, the filterability of the solids in the positive cell increased. Results obtained on dialysed and undialysed ripe sludges, with the use of a membrane, are shown in Figure 10B. The moisture in the cakes produced from undialysed sludge was 81.4 per cent and in the dialysed material 72.0 per cent. Removal of substances from the sludges by dialysis resulted in material increases in the rate and degree of dewatering.

Supernatant digester liquor contains relatively large amounts of materials in solution, and on the basis of dry solids present requires rather large amounts of ferric chloride to produce a dry cake and clear effluent. The effect of these substances on the quantity of electrolyte required is illustrated in Figure 11, where the percentage filtrate of dialysed and undialysed sludge supernatant is plotted after treatment with optimum amounts of ferric chloride. The quantity of ferric chloride required after dialysis was about one-eighth that required without dialysis, and a much dryer cake was produced.

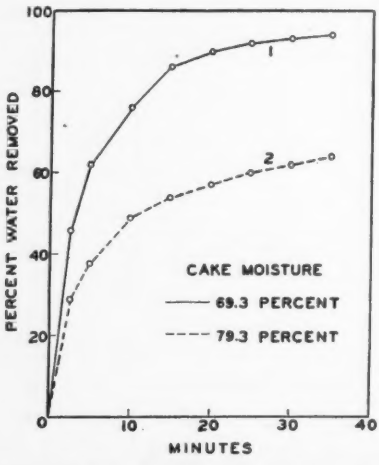

FIGURE 11.—Reduction in ferric chloride required to produce dry cake: (1)—dialysed using 0.3 per cent $FeCl_3$ on dry solids basis; (2)—undialysed using 2.5 per cent $FeCl_3$.

Chemical Changes and Electrodialysis

Fresh Solids

Fresh solids were dialysed against distilled water in a three-compartment cell, with the sludge in the center and parchment paper membranes. The analytical results showing the removal of compounds during electrodialysis are presented in Table III. Analyses of the fresh solids used showed that silica made up 57.4 per cent of the fixed matter in the solids. Phosphates and sulfates were the only anions present in any great quantity. The phosphorus calculated as phosphorus pentoxide was found to be 4.64 per cent of the total ash. It would be expected that a high percentage of phosphorus would be present not in the mineral matter of the domestic sludge but rather in combination with organic material, especially with the proteins or degradation products, or as an adsorbed phosphate ion. Sulfates would be expected to be present in the mineral matter in greater proportions than the phosphates.

TABLE III.—Chemical Changes After Electrodialyses

	Fresh Solids	Dialysate Cathodic Compartment	Dialysate Anodic Compartment
Total solids (p.p.m.)	51,600	1,955	922
Volatile (p.p.m.)	39,300	985	631
Ash (%)	23.8	49.5	31.6
NH_3–N (p.p.m.)	124	57	5
Organic-N (p.p.m.)	1,585	53	15
Protein*	9,900	331	94
pH	5.3	8.0	3.2
SiO_2 (p.p.m.)	7,065	82	15
Fe_2O_3 (p.p.m.)	802	95	4
Al_2O_3 (p.p.m.)	879	0	10
P_2O_5 (p.p.m.)	570	60	162
CaO (p.p.m.)	1,618	369	4
MgO (p.p.m.)	287	59	2
SO_4 (p.p.m.)	631	10	22
Cl (p.p.m.)	81	32	87
P_2O_5 (% of ash)	4.64	6.2	55.7
CaO (% of ash)	13.15	38.0	0.63
Protein (% of volatile)	25.2	34.0	14.0

* Assuming all organic nitrogen in fresh solids as protein.

The analysis of the dialysate in the cathodic compartment, calculated to a volume equivalent to the fresh solids used, is shown in Table III. The material in this dialysate was flocculent and light brown in color. It formed larger flocs on heating, giving evidence of coagulation. The results show that this material was high in proteins, iron and silica, with some phosphorus present. There was also a large quantity of calcium present, accompanied by a pH of 8.0 of the liquid. The floc formed was evidently an iron phosphoproteinate. Formation of a light brown flocculent material is also noticed when sewage is treated with an iron salt.

The material in the anodic compartment was dark gray in appearance; suspended solids were not in evidence. It had a strong acid odor and on evaporation formed a thick syrupy mass. When it was dried in the oven overnight and cooled, a hard, brittle, glass-like substance was formed. On ignition, volatile matter was lost, but no combustion took place. (The loss of volatile matter on ignition of ash from fresh solids and ripe sludge in connection with sludge balances in treatment plants will be discussed in another paper.) The analysis shows that this material contained considerable amounts of phosphorus, P_2O_5, forming 55.7 per cent of the fixed matter. Since phosphorus was determined in this instance in the ash, a certain amount may have been lost during the ashing process. Very small quantities of sulfates passed through the membrane and were possibly tied up in nonionizable material.

The removals effected by the electrodialysis were: of NH_3-N, 62 p.p.m. or 50 per cent; of P_2O_5, 222 p.p.m. or 49 per cent; and of CaO, 373 p.p.m or 23 per cent.

To obtain further information on what materials would migrate and what the effect would be of the substances passing through the membrane on the dewatering of sludge, electrodialysis of sludge against sludge was carried out for a considerable period to produce great variations in the physical nature of the sludges. Some of the results obtained with electrodialysis of fresh solids against fresh solids are shown in Table IV. The sludge in the positive compartment lost water by electroendosmosis and became light brown in color and very gelatinous. It formed stable jelly-like masses on dilution with water. Addition of alkali caused pronounced swelling, but no coagulation took place with extremely large amounts of ferric chloride. Examination of the analyses shows that this jelly-like sludge nearly doubled in organic nitrogen and almost tripled in P_2O_5. The sludge in the negative compartment lost relatively little organic nitrogen and the protein material in the volatile solids remained nearly the same, but the P_2O_5 content of the fixed solids was greatly reduced. This sludge was readily filterable, requiring only a fraction of the ferric chloride needed for dewatering of undialysed fresh solids.

TABLE IV.—Chemical Changes in Sludge Electrodialysed by Using a Ceramic Membrane

Determination	Fresh Solids	Sludge Negative Compartment	Sludge Positive Compartment
Total solids (%)	5.16	5.23	8.70
Volatile solids (%)	3.93	3.69	6.70
Fixed solids (%)	1.23	1.54	2.00
Organic N (p.p.m.)	1,585	4,180	3,040
Protein (p.p.m.)	9,900	9,250	19,000
P_2O_5 (p.p.m.)	570	438	1,526
Protein (% of volatile)	25.2	25.0	28.4
P_2O_5 (% of fixed)	4.64	2.84	7.6
Fixed (% of total)	23.8	29.2	23.0

Ripe Sludge

Electrodialysis experiments were conducted in a three-cell chamber with the ripe sludge in the center compartment and distilled water in the outer cells.

Graphite electrodes were placed in the distilled water compartments, and a current of 0.1 to 0.4 ampere at 22 to 24 volts was applied for a given time. After electrodialysis had proceeded for specified times, the contents of each compartment were removed, the sludge was analyzed for moisture, volatile matter, pH, nitrogen and phosphate, and the coagulant demand and drainability were determined, whereas the liquids were analyzed for nitrogen phosphate and pH. Potentiometric titrations of the sludges were made with 0.1 normal HCl. Some analyses of the original and dialysed sludges are shown in Table V.

TABLE V.—Analyses of Dialysed Ripe Sludges

Electrodialysed (hr.)	pH	Total Solids (%)	Vol. Solids (%)	Vol. Solids (gm./l.)
0	7.2	5.61	53.5	30.0
3	7.1	5.63	53.2	29.3
6	6.7	5.25	54.8	28.8
12	6.6	5.20	54.9	28.5
24	6.6	5.11	55.3	28.2
Decrease (%)	—	8.8	—	6.0

The results show a gradual decrease in pH and percentage total solids, and a relative increase in the percentage of volatile material, but a decrease in quantity of volatile material. The relative increase in volatile solids shows that the soluble inorganic material was removed from the sludge more rapidly than was the soluble organic material. The change in pH values indicates that the soluble material affects the buffer capacity of the sludge. The pH values of the anodic and cathodic compartments were as follows:

Hours	Cathode	Anode
3	10.7	3.2
6	11.6	2.3
12	11.8	2.3
24	11.6	2.2

Titrations of the undialysed and dialysed sludges with 0.1 normal HCl, plotted in Figure 12, show the changes

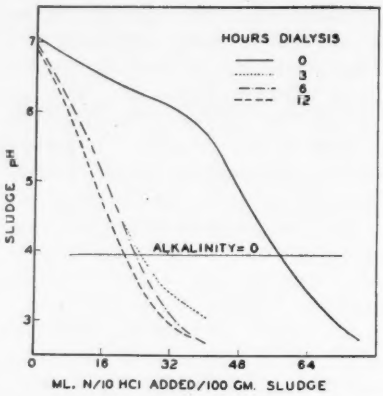

FIGURE 12.—Changes in buffer action as indicated by titration of undialysed and dialysed sludges.

in buffer action caused by dialysis for different periods of time. After 3 hours most of the changes had been completed. The undialysed sludge required 58 ml. acid per 100 grams sludge to neutralize the bicarbonate alkalinity, whereas the dialysed sludges required from 22 to 26 ml.

TABLE VI.—Analyses of Sludge and Liquids for Nitrogen and Phosphorus (Expressed in mg. per 500 grams wet sludge)

Dialysis (hr.)	Chamber	P_2O_5	NH_3-N	Org. N	Total N
0	sludge	436	257	944	1,201
3	sludge	416	131	935	1,066
	positive	20	1	0	1
	negative	1	105	4	109
	total	437	237	939	1,176
6	sludge	304	84	844	928
	positive	136	1	2	3
	negative	0	172	2	177
	total	440	257	851	1,108
12	sludge	259	105	790	895
	positive	192	1	2	3
	negative	0	121	1	122
	total	451	227	793	1,020
24	sludge	200	34	785	819
	positive	248	2	4	6
	negative	4	66	6	72
	total	452	102	795	897

Results on the changes in nitrogen and phosphorus of the sludge and of the liquids are given in Table VI. In spite of the fact that the balances do not check accurately, the system showed a gradual lowering in total nitrogen due to volatilization of ammonia in the strongly alkaline cathodic cell, and an apparent breakdown of organic nitrogen in the sludge to simpler diffusible compounds, probably ammonia or simple amines.

Migration of the phosphorus to the anodic compartment began after about half of the ammonia originally in the sludge was removed (after 3 hours' dialysis), and after 24 hours more than half of the phosphorus had migrated.

TABLE VII.—Vacuum Filtration of Electrodialysed Sludges with Ferric Chloride (Filtration Time in Seconds)

Iron Dosage as Per Cent of		Electrodialysical				
Total Solids	Volatile Solids	Raw	3 Hr.	6 Hr.	12 Hr.	24 Hr.
0.71	1.33	434	—	—	—	—
1.07	2.00	106	—	—	—	—
1.43	2.67	54	—	—	—	—
1.78	3.33	53	—	—	—	—
2.14	4.00	41	—	—	—	—
0.36	0.67	—	405	—	—	—
0.53	1.00	—	198	—	—	—
0.71	1.34	—	102	—	—	—
0.89	1.67	—	42	—	—	—
1.07	2.01	—	35	—	—	—
1.42	2.68	—	22	—	—	—
0.40	0.73	—	—	752	—	—
0.60	1.09	—	—	1,100	—	—
0.80	1.46	—	—	131	—	—
1.00	1.83	—	—	48	—	—
1.20	2.19	—	—	33	—	—
1.60	2.92	—	—	30	—	—
0.41	0.75	—	—	—	900	—
0.61	1.12	—	—	—	207	—
0.81	1.49	—	—	—	75	—
1.02	1.87	—	—	—	34	—
1.22	2.24	—	—	—	27	—
0.45	0.82	—	—	—	—	446
0.68	1.22	—	—	—	—	90
0.90	1.63	—	—	—	—	35
1.22	2.04	—	—	—	—	48
1.35	2.44	—	—	—	—	44

The effect of electrodialysis of a sludge on its vacuum filtration and ferric chloride requirements is illustrated in Table VII. The amounts of iron required are given on the basis of total solids and volatile material. The results show, in general, that the iron demand is reduced by electrodialysis. Perusal of the table shows also that with the same amount of volatile matter, the iron requirement to obtain the same filtration time decreases after dialysis.

The relation between the percentages of ammonia and P_2O_5 removed by dialysis and the filtration time required after various periods of dialysis, using 1 per cent $FeCl_3$ as Fe on a total solids basis, is illustrated in Figure 13. The filtering time was reduced during the first three hours when 50 per cent of the ammonia and less than 6 per cent of the P_2O_5 were removed. Offhand, it would appear that the removal of the ammonia, mostly present in the form of ammonium bicarbonate, was responsible for the reduction of dewatering time and the decrease in iron requirements, unless a short-time electrodialysis changes the manner in which the phosphate is held in the sludge, thereby changing the coagulant demand. Previous results have shown that the form of phosphate was important in connection with sludge volume. In electrodialysis of sludge, the ammonia moves to the cathode, and the bicarbonate and phosphate to the anode. The low pH of the material in the anodic chamber causes decomposition of the bicarbonate to water and carbon dioxide, the majority of the latter being discharged into the atmosphere. If the liquids from the anodic and cathodic cells are again mixed with dialysed sludge, the effect of the ions present should be exerted on the coagulant demand.

A series of experiments were conducted to determine the coagulant demand of sludge dialysed for 24 hours

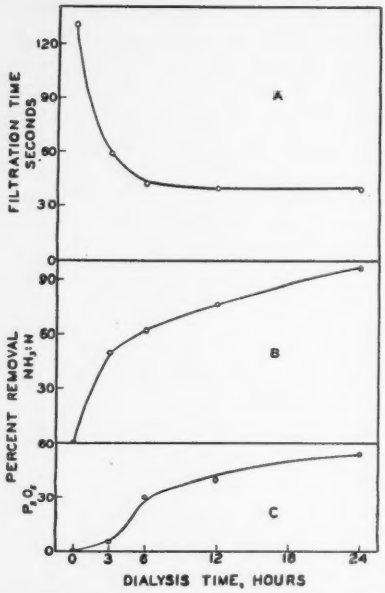

FIGURE 13.—Relation between removal of ammonia and P_2O_5 by dialysis and filtration time.

and mixed with liquor from the anodic and cathodic cells. The results of a set of experiments where sludges were mixed with equal amounts of distilled water, or dialysates, and ferric chloride was added to determine the dewatering time, are shown in Table VIII. The quantity of Fe added was in all cases 200 mg. Fe as $FeCl_3$ per liter of sludge-liquid mixture. In the cases where anodic and cathodic liquors were mixed with the sludge, the pH values were also adjusted to the sludge-water mixtures by the addition of acid or alkali. Finally, separate sludge and cathode liquor mixtures received ammonia nitrogen in the form of ammonium chloride to make up for the ammonia lost from the liquor during the dialysis process (No. 6), and another mixture received ammonia nitrogen in excess (No. 7). For comparison, the results on undialysed sludge mixed with an equal amount of distilled water are included.

TABLE VIII.—Filtration Time of Dialysed Sludges with Equal Amounts of Dialysates and Fe Added

No.	Mixture	pH Mixture	Filtration Time (sec.)	pH Filtrate
1	Sludge and water	6.8	46	5.3
2	Sludge and anode liquor	9.3	121	7.3
3	Same, pH corrected	6.8	35	5.5
4	Sludge and cathode liquor	4.8	340	3.8
5	Same, pH corrected	6.8	385	5.3
6	Sludge and anode liquor and 320 mg. NH_4-N/l. as NH_4Cl	6.8	37	5.3
7	Sludge and anode liquor and 2,640 mg. NH_4-N/l.	6.8	38	5.3
8	Sludge, not dialysed, and water	6.8	423	—

The results show that the time required for vacuum filtration of undialysed sludge-water mixtures agrees rather well with the time required for the pH corrected sludge-anode liquor mixture. Perhaps the most interesting fact is that the additions of the contents of the cathode cell, containing the ammonium ions and corrected to the same pH as the sludge water mixture, did not increase its coagulant demand or dewatering time. When the ammonium content was increased to the original, no increase in dewatering time occurred. Even with excess quantities of ammonia nitrogen, added in the form of ammonium chloride to prevent changes in pH values, no increase in coagulant demand was noticed.

Addition of the contents of the anode cell, containing the phosphate ions, to the dialysed sludge increased the coagulant demand and filtration time to approximately the same as for the original sludge.

Since the pH of the anodic liquor was 2.2, it may be assumed that considerably small quantities of bicarbonate ions were present in the neutralized liquor than were originally removed from the sludge. The increase in coagulant demand by addition of the anodic liquor, therefore, could not be attributed to the negative bicarbonate ions, but must be due to other negative ions.

Discussion

The effect of phosphates added to fresh solids treated with ferric chloride was similar to the effect on ripe sludge. When lime was added to ferric chloride treated sludge receiving phosphates, there was an effect on filtration time irrespective of the pH values, but no pronounced effect on the moisture in the cake; in other words, the moisture holding capacity was not greatly changed. This may mean that the lime made the phosphates inoperative, possibly by precipitation.

Addition of phosphorus to digester supernatant increased markedly the amounts of suspended solids remaining in the liquor, with large percentage increases in the ash content of the suspended solids. Since larger quantities of phosphorus did not further increase the suspended solids in the liquor, but were apparently precipitated in the sludge, it would seem that only certain constituents of the liquor were affected by the phosphates. These constituents, after action of the phosphates, were finely divided, did not settle readily and caused increased turbidity. The quantities of sludge formed increased in relation to the degree of precipitation of the phosphorus compounds, and since the amount of solids did not materially increase, the sludge formed had a lower concentration or a greater water holding capacity.

It appears that there is a general relation between the type of phosphates present or added and the clarification, filtration and sludge volumes. When phosphates are precipitated by ferric chloride in distilled water, the phosphates which show the greatest precipitation produce the poorest clarification, the greatest retarding effect on filtration, and the largest volumes of sludge. In all cases, the effects were greatest with sodium phosphate. The question naturally arises whether the sodium or the phosphorus is mainly responsible. The experiments showed that only relatively large quantities of sodium hydroxide caused a reduction in dewatering time, whereas the effect of sodium phosphate was much more pronounced.

Phosphates are relatively more water soluble in a slightly acid medium than in a slightly alkaline medium. Lime decreases the solubility. The trivalent phosphate ion is adsorbed by weakly negative sludge particles causing dispersion of the sludge particles and decreasing the reaction with the positively charged trivalent ferric ion. Addition of more ferric chloride produces a very clear filtrate, indicating that the finely divided particles charged with phosphate are precipitated by the increased amounts of $FeCl_3$. It is possible that the phosphorus may aid hydrolysis of $FeCl_3$ with removal of the finely divided sludge particles or precipitation of the non-reacting iron by the phosphates. Raising the pH value of coagulation by adding phosphate buffer results in higher iron requirements.

Direct electrolysis has no measurable flocculating effect on sewage and no dewatering effect on fresh solids or ripe sludge. When the products of electrolysis are separated by a semi-permeable membrane, however, the sludge is made relatively unstable. The ash of sludges shows that various ions are present, including calcium and phosphates. Dialysis has shown that these ions exist principally combined as soluble salts. The adsorption of these salts by the micelles is one of the causes of the stability and dispersion of colloids and the binding of water.

The sludges also contain proteinaceous matter. Protein salts show a complicated physicochemical behavior. When protein unites with phosphoric acid, forming an insoluble compound, 100 parts of protein unite with 3.6 parts of metaphosphoric acid. These proteins in water have a reaction of

pH 5.0. The compounds of metaphosphoric acid are stable in an excess of the acid. The actual linkage with compounds of phosphorus in sludge is obscure, but the evidence presented indicates that the type of phosphate is important, while indirect evidence indicates that the state of oxidation of the phosphorus may be important in the formation of an iron phospho-proteinate floc when ferric chloride is added. That the state of oxidation of the phosphorus may be important is indicated by the fact that the addition to sewage of minute quantities of oxidizing agents, such as potassium permanganate, brings about a more efficient flocculation by iron salts and aids materially in the dewatering of sludge treated with $FeCl_3$. When the phosphate ions are removed by electrodialysis, the instability of the proteinaceous matter is increased. Dissociation of the proteins and protein salts, which form gelatinous masses, results in shrinking, more rapid dewatering and a lower moisture content in the cake. Removal of phosphate ions by electrodialysis through a membrane results in great reductions in coagulant and higher filtration rates of sludge, whereas addition of the dialysate containing phosphorus impedes filtration and increases the iron demand. On the other hand, additions of ammonia or dialysate containing ammonia and bicarbonates have virtually no effect. It appears, therefore, that phosphates and protein (or protein salts) are of great importance in connection with dewatering of sludge, sludge volume production and coagulant demand.

Trade wastes from the fermentation industries, containing larger quantities of phosphorus than sewage, may be expected to be more difficult to treat by coagulation than domestic sewage. Sludges formed from such wastes alone or in conjunction with sewage sludge are more voluminous and more difficult to dewater than domestic sewage sludge. Experience has shown that sludges formed from these wastes consist of finer aggregates and do not compact so readily as sewage sludge. Experiments have also shown that the coagulant demand, volume of sludge produced and difficulty of dewatering are greater with distillery than with brewery waste, and greater with penicillin waste than with yeast waste. The quantities of phosphates present in these wastes follow the same pattern. All these wastes contain considerable quantities of proteins or protein salts in addition to the relatively larger amounts of phosphates. Incidentally, activated sludge contains more protein and phosphorus than does plain settled sludge, and is usually more difficult to dewater.

Summary

Phosphates are a normal constituent of domestic sewage solids. Fermentation wastes contain appreciably higher amounts of phosphorus than sewage. Studies pertaining to the effect of various types and different quantities of phosphorus compounds on the dewatering of fresh solids, ripe sludge and the coagulation of digester supernatant, and the effect on sludge volume and water holding capacity of sludges are presented, together with an effort to explain the phenomena observed. The results obtained showed that there was a general relation between the type of phosphates present or added and the filtration time, sludge volumes, and clarification of the liquid. Phosphates precipitated to the greatest degree, produced the highest sludge volumes, the greatest retarding effect on filtration time and the poorest clarification. Sodium phosphate showed the greatest effect.

Electrodialysis of the sludges showed that the coagulant demand is greatly influenced by soluble ions, which can be removed, and that the cations did not effect the coagulant

demand of dialysed sludge but that the anions had a pronounced effect. Bicarbonate and ammonia ions did not appear to play an important role, but phosphate ions appeared to be one of the chief controlling factors in dewatering.

Removal of phosphate ions adsorbed on the sludge particles or on the proteinaceous substances present caused instability and increased the filterability with lower quantities of coagulant, indicating that phosphates and protein (or protein salts) are of great importance in connection with dewatering of sludge. Trade wastes containing phosphorus compounds are more difficult to dewater, produce larger volumes of sludge, and hold the water more tenaciously than sewage sludge.

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THE EFFECT OF CHROMATE WASTES ON THE ACTIVATED SLUDGE PROCESS AT THE TALLMANS ISLAND PLANT

By Gail P. Edwards and Frederick E. Nussberger

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Several times since the beginning of the war, chromium compounds have been mentioned in the literature as affecting both aerobic and anaerobic biological processes of sewage treatment.

Ross (1) reported that the activated sludge plant at Richmond, Ind., handled without difficulty 1 p.p.m. (Cr) of chromate waste. Jenkins and Hewitt (2) found that 2 p.p.m. of chromium as chromate (0.9 p.p.m. as Cr) will reduce or even stop nitrification in an activated sludge plant, and that 10 p.p.m. (4.5 p.p.m. as Cr) added continuously for two days might cause nitrification to cease and a week or more might be required for recovery. The chromium decreased the biological activity of the activated sludge and seemed to be a specific inhibitor of the nitrifying organisms. The action did not seem to be toxic. At Grand Prairie, Texas, Wells (3) obtained poor settling of activated sludge and unusually low efficiency of treatment because of chromium wastes sufficient in amount to color the aeration liquor yellow. The chromate caused high dissolved oxygen values and interfered with bacterial life, resulting in low B.O.D. results.

Spencer (4) describes a trickling filter plant in which biological action was stopped by chromates, the concentration ranging from 3.5 to 67.6 p.p.m. as Cr.

In contrast to this, Monk (5) concluded from a study of the survival of *B. aerogenes* in chrome plating wastes that 50 p.p.m. chromates as CrO_3 (26 p.p.m. as Cr) might be permitted in sewage without injury to treatment. He believes that the chromium compounds tend to concentrate in the sludge.

Chromium wastes are also said to have interfered with sludge digestion. Wise (6) reported that when 200 p.p.m. of precipitated chromium are present in the sludge the rate of digestion is noticeably reduced, and when the concentration of chromium constantly exceeds 1 p.p.m. a decrease in efficiency of sludge digestion can be expected.

Jenkins and Hewitt (7) observed that in sewage containing as little as 2.6 p.p.m. of chromium as K_2CrO_4 (0.7 p.p.m. as Cr) the B.O.D. values were markedly decreased.

Source and Nature of Wastes

On October 17, 1946, beginning at 5:30 P.M., the Tallmans Island sewage treatment plant received a large volume of a chromate industrial waste. Another but smaller volume was received on October 18 at about 10 A.M. Grab samples of the raw sewage were taken at each time and analyzed for chromium content and pH. The results of analyses are as follows:

	Chromate as Cr (p.p.m.)	pH
October 17, 1946	430	4.2
October 18, 1946	1,440	4.0

The attendant at the grit chamber estimated that the duration of the yellow waste flow was about 30 minutes on October 17 and a short time, perhaps two minutes, on October 18.

Subsequent investigation disclosed that one of the war plants in the area

had turned over 3,000 gal. of a spent chromic acid anodizing solution to a scavenger for disposal. The scavenger, in turn, had dumped the chromic acid waste into a sewer served by the Tallmans Island plant. Samples of the solution remaining in the vat at the war plant were collected and the results of analysis are as follows:

Chromium (per cent by weight as Cr)	13.2
pH	1.2
Specific gravity	1.31

The chromium acid had been used for anodizing aluminum and originally had a pH of about 0.5. In use, aluminum goes into solution and the pH of the solution rises. The pH is maintained at about 0.5 by additions of chromic acid and when the aluminum content becomes too large, the solution is discarded. The 3,000 gal. contained about 4,350 lb. of chromium, or as sodium chromate, about 13,500 lb.

Effects on Activated Sludge Plant

On the morning of October 18, before the second discharge of chromate waste was received, the sewage in the various stages of treatment from the preliminary tanks to the outfall was noticeably yellow in color. Laboratory tests indicated that about 25 p.p.m. of K_2CrO_4 would be needed to

TABLE 1.—Tallmans Island Sewage Treatment Plant, Operating Data, October, 1946

Date	D.O. (p.p.m.)		Nitrogen (p.p.m.)				B.O.D. (p.p.m.)		Susp. Solids (p.p.m.)		Sludge Index	Air Ratio (cu. ft./gal.)
	Aer. Tank Eff.	Final Tank Eff.	Pri. Eff. NH_3 N	Aer. Tank Eff.			Pri. Eff.	Final Eff.	Pri. Eff.	Final Eff.		
				NH_3 N	NO_2 N	NO_3 N						
1	2.0	3.0	30.0	12.5	0.60	0.0	70	21	49	15	1.7	0.25
2	1.0	1.6	—	—	—	—	62	24	34	8	1.4	0.32
3	0.8	2.3	30.0	25.0	0.15	0.0	60	19	37	10	1.2	0.33
4	0.7	1.4	20.0	20.0	0.10	0.0	60	15	35	10	1.3	0.34
5	2.2	2.3	—	—	—	—	70	15	32	7	1.5	0.34
6	1.7	2.2	—	—	—	—	70	15	44	5	1.5	0.40
7	2.5	1.8	25.0	20.0	0.60	0.0	95	19	57	7	1.5	0.38
8	2.1	2.7	30.0	2.5	2.20	4.0	90	14	62	6	1.5	0.35
9	1.0	1.8	30.0	17.5	1.70	3.0	100	15	58	5	1.6	0.38
10	1.6	1.7	25.0	7.5	1.30	1.2	115	12	75	4	1.5	0.34
11	0.6	1.3	30.0	12.5	1.00	2.0	85	14	64	9	1.5	0.30
12	1.0	1.3	—	—	—	—	60	10	42	6	1.5	0.27
13	0.8	1.2	—	—	—	—	70	12	41	4	1.5	0.34
14	0.8	1.5	25.0	17.5	1.25	2.0	115	15	52	4	1.5	0.33
15	1.2	1.4	35.0	15.0	1.00	2.4	80	12	38	5	1.4	0.35
16	0.9	1.6	35.0	15.0	1.25	2.4	80	10	41	5	1.4	0.43
17	0.9	1.6	30.0	20.0	1.00	1.6	60	13	45	31	1.4	0.38
18	(10.4)	(9.2)	25.0	25.0	0.10	0.2	70	20	38	28	1.4	0.33
19	6.9	6.1	—	—	—	—	85	12	70	15	1.5	0.40
20	6.1	4.5	—	—	—	—	60	10	37	18	1.5	0.39
21	5.2	4.9	25.0	25.0	0.25	0.0	115	11	90	13	1.6	0.36
22	4.0	3.3	25.0	20.0	0.15	0.0	75	8	55	10	1.5	0.36
23	5.9	4.8	25.0	25.0	0.10	0.0	75	8	47	14	1.5	0.38
24	2.6	3.5	—	—	—	—	145	13	750	15	1.5	0.34
25	5.9	5.0	25.0	17.5	0.15	0.0	65	7	52	16	1.5	0.36
26	4.7	5.0	—	—	—	—	70	5	68	6	1.5	0.34
27	5.8	5.0	—	—	—	—	90	6	95	10	1.5	0.37
28	5.5	4.8	35.0	25.0	0.85	0.0	95	9	62	5	1.4	0.37
29	4.5	4.2	30.0	25.0	0.75	0.0	80	5	64	5	1.4	0.38
30	4.4	4.5	25.0	25.0	1.70	0.0	85	24	53	9	1.4	0.40
31	4.0	3.7	35.0	25.0	2.30	0.1	95	9	69	6	1.3	0.39

impart this yellow color. On this basis, at least 500 lb. of chromium compounds as Cr were present at that time. It took about 36 hours after the first appearance of the waste for the yellow color to completely disappear from the sewage.

During the period October 15–23, the aeration solids averaged about 2,100 p.p.m. and the return sludge 5,500 p.p.m. The average sewage flow was 18 m.g.d. and the rate of sludge returns was 45 per cent. The only change in operation after receiving the chromate waste was from conventional aeration to step aeration. From October 18 to 21, two-thirds of the sewage entered the aeration tank at the beginning of the first pass with the return sludge, and the remainder of the sewage was added at the beginning of the second pass. Step aeration keeps the sludge in the aeration tanks a longer time.

Pertinent operating data for October, 1946, are shown in Table I.

After the chromate wastes were received, the effluent from the final settling tanks lost its clear, sparkling appearance and became quite turbid. This turbidity did not completely disappear for ten days.

The suspended solids in the final effluent averaged 7 p.p.m. for the first sixteen days of October. On the 17th, they rose to 31 p.p.m., then dropped slightly to 28 p.p.m. on October 18 and gradually decreased to 6 p.p.m. ten days after the first discharge of chromate waste. The suspended solids for the last fifteen days of October averaged 13 p.p.m.

The average B.O.D. of the effluent for the first sixteen days of the month was 15 p.p.m. On the 18th, the B.O.D. rose to 20 p.p.m. and dropped to 12 on the 19th. It averaged only 11 p.p.m. for the last fifteen days of October.

Discussion

In the effluent of many activated sludge plants, the concentration of B.O.D. is less than that of the suspended solids. At the Tallmans Island plant, this relation is reversed and the B.O.D. values are generally higher than those for the suspended solids because of the formation of nitrites and nitrates in the B.O.D. bottles. Because of the decrease in the nitrification after October 16, the suspended solids remained higher than the B.O.D.

On October 18, the determination of dissolved oxygen in the aeration tank effluent indicated values for oxygen above the saturation point. No doubt, this was due to liberation of iodine by the chromate. Theoretically, 2 p.p.m. of chromium in the form of chromate will cause an apparent increase in the dissolved oxygen content of 1 p.p.m. It is interesting that the dissolved oxygen content remained at a much higher level, even 14 days later, than for some time previous to the influx of the chromate waste. Since the air ratio remained practically constant, this may have been caused by a reduction in the activity of the organisms.

Microscopic examinations of the activated sludge during this period showed an almost complete disappearance of filamentous bacteria such as *sphaerotilus*, which had been present in moderate amounts. A few days after the inflow of the chromium wastes, the stalked ciliates also decreased in number.

The chromate waste seemed to have a marked effect on the nitrogen compounds. Before the discharge of chromate waste, the free ammonia ordinarily decreased from about 30 to 15 p.p.m. in passing through the aeration tanks and the effluent contained about 1.0 p.p.m. of nitrite nitrogen and 2.0 p.p.m. of nitrate nitrogen. Immediately after the addition of chromate to the sewage, there was no reduction in free ammonia and practically no nitrites or nitrates were produced. In ten days, the nitrites approached normal values.

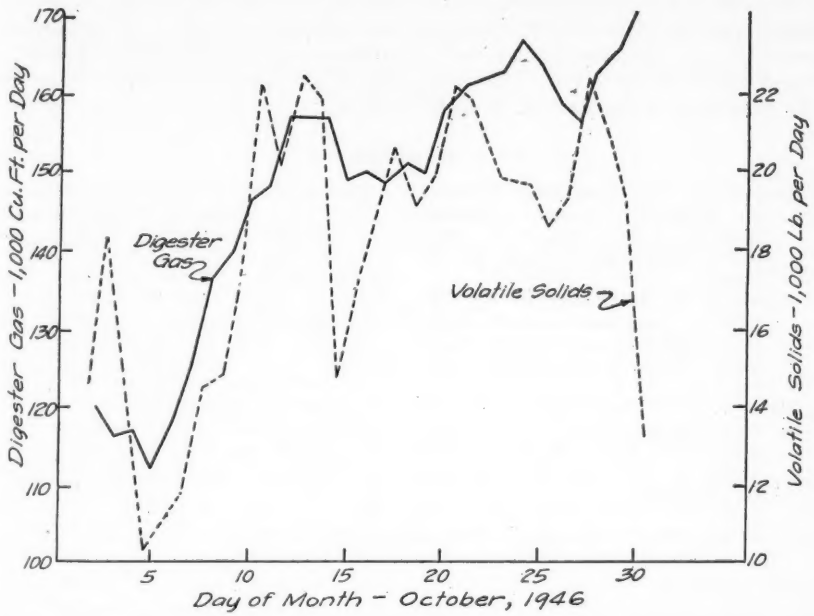

FIGURE 1.—Volatile solids pumped to digesters and gas production at Tallmans Island plant during month of October, 1946. Chromate wastes received at plant on October 17–18.

The settling qualities of the sludge were not affected, as the sludge index remained nearly constant.

Neither the amount of volatile solids pumped to the digester nor the amount of gas produced seems to have been changed by the chromate. Apparently the chromate was not appreciably reduced and precipitated as chromic hydroxide, which would act as a coagulant, nor did the chromium which did reach the digester have any deleterious effect. Any chromium compounds reaching the digesters with the sludge during the 2- or 3-day period were distributed over two tanks and were well diluted. The weight of volatile solids pumped to the digester and the volume of gas produced are shown in Figure 1. Assuming that gasification of solids added on any day would be completed by the third day thereafter, a 3-day moving average was used for the gas. A 2-day moving average was employed for the volatile solids, since an average of two days pumping more nearly represents the solids captured in a day.

Chromic acid and dichromates are considered very strong oxidizing agents but both exist only in acid solution. Although the anodizing solution was strongly acid when discharged into the sewer, it was quickly neutralized by the sewage and converted to the more stable chromate.

The Tallmans Island sewage is dilute and fairly fresh. The waste was received at the plant in two concentrated doses. Little or no reduction of chromate to chromic hydroxide seemed to take place and the soluble chromate was discharged through the outfall.

Summary

The Tallmans Island activated sludge plant, handling an average flow of 18 m.g.d., received more than two tons of chromic acid, calculated as chromium,

in an 18-hour period on October 17–18, 1946. The waste had little effect on treatment except that nitrification ceased for about ten days. This actually resulted in a decrease in the effluent B.O.D. The effluent was turbid for several days, probably because of dead organisms, but this turbidity cleared up with the re-establishment of nitrification.

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CHLORINATION PLANT PROBLEMS AT CITY ISLAND PLANT OF THE ATLANTIC CITY SEWERAGE COMPANY *

By George W. Cameron

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City Island plant visitors are usually quite interested in the method of conveying large quantities of chlorine from the mainland to the sewage treatment plant. This plant is connected to the mainland only by a narrow footbridge about 1,500 ft. long, and all heavy materials must of necessity be transported to it by boat. When decision was made to chlorinate the sewage, transportation of liquid chlorine to this plant became a major item in the planning.

A study of the several means of getting chlorine to the island resolved the problem into four possible solutions:

(1) That 150-lb. cylinders, having a gross weight of 242 lb. each, could be hand-trucked over the footbridge to the plant. This was discarded because the quantity requirements of 3,000 lb. of chlorine daily placed the job in the ton container class, both with respect to unit cost of chlorine as well as the awkward problem of connecting and disconnecting 20 cylinders daily.

(2) That ton containers could be housed on the mainland and unloaded by withdrawing chlorine gas and conveying it to the island through a pipe line attached to the footbridge. This solution, although promising, was finally set aside because of reliquefaction probabilities in the long line exposed to the elements. Effective insulation, preheaters, liquid traps, and other devices commonly employed to combat liquefaction in chlorine gas lines were obviously inadequate to cope with the problem offered by 1,600 ft. of undulating pipe, almost entirely exposed to the weather.

(3) That ton containers could be transported to the island on barges. This was eliminated from further consideration because the apparatus and labor involved in moving 45 ton containers each month created quite an operation and navigation problem. Loaded ton containers have an average gross weight of about 3,600 lb. each.

(4) That the ton containers could be housed on the mainland and discharged by piping liquefied anhydrous chlorine to the island. The disadvantages of this method appeared to be less ominous than the other three solutions and this plan was finally adopted.

Design and Construction Problems

The principal problems involved in this design were: (*a*) construction of a chlorine-tight pipe line supported on a wooden footbridge, constantly subject to wind and tide vibration, (*b*) provision for the thermal expansion and contraction of this long exposed line, (*c*) protection of the line from hydrostatic rupture due to expansion of liquid chlorine which might be trapped therein, and (*d*) provision of an essential safety device which would automatically stop escape of liquid chlorine from the ton containers in case of line breakage due to coastal storms, runaway barges, etc.

Pressures

Considering that the chlorine pressure in the line is controlled by the

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temperature of the containers, properly sheltered on the shore, a peak probable ton container temperature of 105° F. was selected. This corresponded to a chlorine vapor pressure of 154 p.s.i. gauge or a total pressure of 176 p.s.i. when the effect of inert gases were considered on a fresh container stored at this temperature.

Obviously such probable pressure required the use of extra strong pipe and fittings. The provision of pipe and fittings designed for a working pressure of 250 p.s.i., together with insistence on good workmanship, yielded a chlorine-tight line.

Workmanship

In the actual construction of the line, considerable trouble was experienced with pipe fitters who did not appreciate the necessity of clean, sharp threads cut full length and full depth, and jointed with litharge and glycerine or white lead and oil. Careless workmanship and the use of proprietary jointing compounds caused a number of leaks during the initial operation of the line. In every case, these faults were eliminated by the inspector making certain that each joint was reworked and secured according to specifications.

It cannot be over-emphasized that the best mechanical work and strictest adherence to luting specifications must be enforced on pipefitters erecting chlorine pipe lines. Care must also be taken to make certain that tapered thread couplings are furnished with the pipe. A number of pipe companies normally supply straight thread couplings. These are not satisfactory for chlorine.

Contamination by organic impurities from pipe linings and excess luting compounds is of such importance that it must not be neglected. Liquid chlorine will partially dissolve oils and the lacquer of pipe coatings, later depositing compounds in pipe, valves, and chlorinator of the gas phase of the system. Before laying the pipe line, the interior of each length of pipe was cleaned with carbon tetrachloride, and all valves and fittings were degreased with the solvent. Care was also taken to prevent luting material from entering the pipe at threaded joints.

Provision for Expansion

A flexible U-bend type of expansion joint was specified rather than the slip-joint device, since the avid attack of chlorine on all fluid greases and oils made the lubrication of slip-joints impossible.

For the 1,500 ft. of pipe, which is virtually in a straight run along the bridge, the calculated increase in length for a temperature rise of 140° F. is 16.95 inches. To absorb this, five expansion bends were designed having a radius of curvature of 1 ft. 3 in. and a length, after forming, of 5 ft. 6½ inches. These were spaced to absorb equally the pipe expansion.

It was necessary to fasten the pipe securely on each side of the expansion bends and then cold-spring the bends one-half the distance of the calculated expansion to be absorbed by each bend. Anchorage was accomplished by welding a base plate to the pipe at least 15 ft. from the start of each bend and bolting the base to a 2 by 6 in. wood floor member of the bridge.

Connections of the expansion bends to the pipe on each side were made through four-bolt ammonia flanges, using compressed asbestos gaskets. Except for the one anchor plate before each expansion bend, the pipe was allowed free movement at all other points through use of oversize pipe straps. It is interesting to note that bridge construction did not permit readily the usual method of laying the expansion bends horizontally. Instead, the bends were placed in a vertical position along the line. This deviation from conventional practice results in no operating difficulties, but it does

increase the time required for emptying the system prior to shutdowns for repairs.

A not generally understood characteristic necessitates special design precautions in order to avoid hydrostatic rupture. For example, a container 88 per cent liquid full at room temperature becomes 100 per cent liquid at 154° F. due solely to this expansion. Likewise, a pipe line 100 per cent liquid full with valves closed at each end will, upon substantial temperature elevation, be subjected to unlimited hydrostatic pressure, resulting in rupture.

In the chlorine industry, it is common practice to provide expansion chambers in long liquid chlorine lines. These usually consist of closed chambers mounted above and connected to the highest point of the line. Thus, a 150-lb. cylinder, having a total volume of 1.925 cu. ft. and connected to a high point of the line, was provided for protection against hydrostatic rupture of the line.

Safety Precautions

One of the first questions usually asked on a chlorine installation is, "What will happen if we lose a ton of chlorine?" The usual answer to this is simple and truthful, consisting merely of the observation that it is physically impossible for a ton of chlorine to be quickly lost as a gas. The refrigeration of the container by escaping gas slows down the discharge to the point where complete emptying is a matter of days rather than minutes.

Plants withdrawing chlorine as a liquid, however, are faced with the very real possibility of the loss of astonishingly large quantities of chlorine in a relatively short time. Being 450 times more dense than gaseous chlorine, and refrigeration not being created, escaping liquid chlorine can completely empty a ton container in a matter of minutes.

Because of the exposed location of the pipe line, it was necessary that an automatic safety device be provided to stop the liquid chlorine flow in case of line breakage. A vertically operating ball check valve was selected as the most promising device of this sort. The weight of the ball and the annular space between the ball and cage control the rate of flow of liquid through the check valve, so that the ball remains at rest at maximum operating rates but is lifted up to its seat in case the flow increases beyond the design rate.

Check valves constructed for liquid chlorine tank car service form the basis of design for those employed in this installation. These valves are built to close when liquid chlorine is withdrawn from a tank car at the rate of 8,000 lb. per hour. They consisted originally of a Monel cage threaded for 1¼-in. male pipe connections at each end, and having a ¾-in. diameter ball retained inside by a Monel pin inserted through the diameter of the cage. Revision for this installation consists of removing the Monel pin and welding tight the two opposing holes, placing a sleeve fitted with retaining pins inside the cage and adding steel companion flanges to each end. The same ball functions at the lower closing rate in the reduced annular space between it and the inserted sleeve.

Based on the plant's present chlorinator capacity, the maximum chlorine withdrawal rate for either ton container connected alone might be as high as 8,000 lb. per day. Normal rushing of liquid chlorine into the line upon turning on a fresh container soon proved that the original design figure of six times the maximum withdrawal rate provided a much too sensitive ball. This was increased 50 per cent by trial and error experimentation, and today the closing rate is 3,000 lb. of liquid chlorine per hour. This appears to be sufficient to keep the ball in repose during normal fluctuations in flow and yet it provides sufficient sensi-

tivity to insure the ball lifting in case of heavy discharges.

Complete Installation

The chlorine equipment installation as installed consists essentially of the following:

1. A ton container storage platform and scale house on the mainland. In the scale house are two scales, each holding one ton container of liquid chlorine, which connects to the pipe line through a line valve and ball check valve. An inverted expansion tank connects to the pipe line at the junction of the two ton container lines.
2. Sixteen hundred feet of uninsulated ¾-in. extra heavy black iron pipe, with five expansion bends, traversing the full length of the footbridge between mainland and island.
3. A chlorinator building on the island housing liquid chlorine evaporators and vacuum type, solution feed chlorinators.

After five years of service, this liquid chlorine transmission system is giving excellent service. We are extremely appreciative of the efforts of the Technical Division of the Pennsylvania Salt Manufacturing Company, under the supervision of George W. Benbury, Service Engineer, for the solution of a problem which gave much concern.

Upon operating the plant for some time, it was apparent that some sort of a trap would have to be installed between the evaporators and chlorinators to reduce the amount of impurities, commonly called "taffy," which was causing chlorinator trouble. The design contemplated that by reason of the liquid withdrawal from the cylinders, more of the 0.2 per cent by weight of impurities would reach the evaporators compared to the amount usually encountered in the gas withdrawal direct to chlorinators, but it was thought that the evaporators would act as a separator. This theory did not prove to be a fact. In order to overcome this problem, separators six ft. high and eight inches in diameter were installed between the evaporators and the chlorinators. Shutdown of chlorinators due to clogging have been greatly reduced by the addition of the two separators.

Industrial Wastes

THE INDUSTRIAL WASTE PROBLEM. II. STRAWBOARD, PETROLEUM AND DISTILLERY WASTES *

By Don E. Bloodgood

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In studying industrial waste and stream pollution problems, one is soon impressed that there are two groups of people who have particular interests that do not seem to be of a like nature. These two groups are the public, composed of individuals and organized groups and industry. Their divergence of opinion is over the matter of economics. They both know that basically it is to the advantage of both groups to have clean streams. The public usually wants clean streams at any cost, and industry wants clean streams at a cost that will not appreciably interfere with profits. Obviously, it is impossible to satisfy both parties completely. Therefore, it is necessary for them to work together, arbitrating their differences but cooperating to accomplish the elimination of stream pollution.

Some manufacturers have taken the industrial waste problem seriously. They no doubt believe that the time is at hand when the public will demand improved stream conditions. How is industry meeting this demand? In some instances the whole industry has organized for this sole purpose. It should be noted that these new organizations are not formed to fight legal battles, but are research groups bent on finding solutions to the waste disposal and recovery problems. The National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries), Inc., is probably the largest group to undertake coordinated research and investigation for a whole industry. The petroleum industry has competent men working on its problem and their studies, such as Hart's treatise on "The Evaluation of the Toxicity of Industrial Wastes, Chemicals, and Other Substances on Fresh Water Fishes," have been useful in waste treatment studies. The steel industry is sponsoring cooperative research on pickling liquor disposal at Mellon Institute under the direction of R. D. Hoak. Many of the fermentation industries have individually sponsored research which has been beneficial for both the public and the industries. The above mentioned groups are only a few of those who are undertaking private and cooperative studies.

Most states now have stream pollution control laws. Some of the laws could be amended, however, to make them more effective. An effective law is one which is helpful as well as forceful. Helpful legislation is not necessarily dependent upon the issuance of grants and loans.

Selling conservation of wasted usable products and promoting good housekeeping are among the things that can be done to encourage industry. If the dairy industry can be convinced that their usual 2 per cent loss of incoming milk can be reduced by half, they will realize that their waste problem can be cut in half and that they will re-

* A series of special papers by members of the FSWA Committee on Industrial Wastes.

cover a quantity of usable product that will have a value which will offset some of the cost of treatment of the actual waste waters. Some of the fermentation interests have learned that the so-called waste products have a dollar value if they can be recovered.

Some industries now claim that the cost of recovery of some products is far more than sales value. In such cases the industry should feel encouraged because any revenue means a slight reduction in the cost of waste treatment. In such cases it is up to the public in some way to encourage studies which will result in a more efficient method of recovery. Forced operation of a recovery process will not be too successful unless there is, at least, a partial compensation. The owners of metal plating plants are not enthused about treating the wastes from their plants, but if they can be made to realize that a mineral-free water, possibly produced in treating their wastes, is more suited for plating work than is well water, and that such mineral-free water can be produced more economically from their waste waters than from fresh water, they will lose no time in adopting such a waste disposal system. They will also give the operation of the process their very best attention.

This same philosophy can be applied to the handling of practically all industrial wastes.

The writer attempts in the following to review some facts relating to the wastes of the strawboard, petroleum, distilling and alcohol industries.

Strawboard Wastes

Straw is used quite extensively in the middle west in the manufacture of paper. The straw is cooked wet with chemicals under steam pressure for several hours, and in some plants there is drainage from the straw after the cooking. The volume of such drainage is very small but the concentration of total solids and B.O.D. are very high.

After the cooking process the straw fibers are washed and beaten. It is from this process that the great quantities of solids and dissolved matter are obtained. Many of the solids are so fine that they are not even removed on coarse filter papers. Some solids are lost in the water from the paper machine. A part of the fibers lost in the machine are of sufficient length to be used in the making of paper.

It is difficult to give average concentrations of the three wastes or for the total waste from a strawboard mill because of the variation in methods used in preparing the pulp in the different mills. Table I gives data obtained from certain mills in Indiana, Illinois, and Iowa.

The losses in a strawboard mill depend to some extent upon the quality of the straw that is being used. Figures obtained at one Indiana mill show that about 30 per cent of the weight of the incoming straw goes out in the waste water. A large percentage of the material lost is not usable in the paper as it is made up of earth, chaff, and weeds. It seems entirely possible that this material might be removed before baling and thus save on both freight and waste disposal facilities, and also improve

TABLE I.—Analyses of Strawboard Wastes

Sample	Total Solids (p.p.m.)	Suspended Solids (p.p.m.)	5-Day B.O.D. (p.p.m.)
Rotary waste	87,705	17,800	20,900
Beater and washer waste	7,095	2,951	1,665
Machine water waste	2,729	931	314
Combined plant wastes	3,835	1,707	847

the quality of the paper being manufactured.

At the Ball Brothers mill in Noblesville, Ind., nearly 100 acres of lagoons are used as the means of disposal. The total waste is discharged into the lagoons where the solids settle out. Decomposition of the waste takes place with the evolution of some gas. As the waste travels through the lagoons it apparently undergoes further oxidation, as samples of lagoon waters have been found with B.O.D.'s which were 10 per cent of those in the wastes discharged to the lagoons. Such a method of disposal is inexpensive from the standpoint of equipment, but not all mills have unlimited land area available for lagoons, and even when there is a large area available, the deposition of about 30 tons of solids per day (for a 100-ton mill) will fill up even a large lagoon in a few years.

A pilot plant has been operated at the No. 2 Mill of the Terre Haute Paper Company at Terre Haute, Ind. for a number of months. Indications are that primary sedimentation will remove about 50 per cent of the suspended solids and about 9 per cent of the B.O.D. A trickling filter handling the settled waste, with a removal loading of 1.25 lb. per cu. yd. and recirculation, produced an effluent with a B.O.D. of about 275 p.p.m. as long as the weather was warm. Cold weather seriously decreased the efficiency of the filter.

It is apparent that more information on secondary treatment of strawboard wastes is necessary before large plants can be constructed. The construction of primary treatment works can, however, relieve the heavy sediment load from many of the streams. It is possible to dispose of the primary sludge solids in lagoons, or the sludge can be dewatered by vacuum filtration with heavy applications of coagulating chemicals.

Petroleum Wastes

As the years have gone by the magnitude of the waste disposal problem of the petroleum industry has decreased, at least in the volume of waste that needs to be disposed of. Less than forty years ago the industry was faced with the disposal of large quantities of a waste which now is the source of all gasoline. The development of the automobile has made the one time waste product (gasoline) of one industry its main item of manufacture. Other waste products have become commercial items of importance and are, of course, no longer a problem to those interested in waste treatment and disposal.

The utilization of waste products in the past is at least encouraging to those who must find means for disposing of the remaining troublesome materials. Weston (1) describes many of the waste products from the industry and a listing of them is again given here:

Oil Production Wastes:

1. Drilling Muds
2. Salt Water
3. Natural Gas
4. Oil

Marketing Wastes:

1. Tank Truck Washings
2. Barrel Washings

Refinery Wastes:

1. Oil
2. Waste Caustic
3. Acid Sludge
4. Emulsions
5. Condensate Waters
6. Tank Bottom Sludges
7. Coke
8. Acid Gases
9. Waste Catalysts

Brines

The salt water or brine is the most troublesome of the wastes from the oil fields. The brines vary in salt con-

centration from a few thousand to over 250,000 p.p.m. Though these waste waters contain large quantities of some important chemicals and elements, it is still thought more economical to return the brines to the earth through injections wells, even though they are expensive to operate. There is little hope that the sodium chloride that might be produced each day from the oil well brines could ever be used, since it has been estimated that the Mid-Continent and Gulf Coast fields alone produce daily over four times the annual consumption of crude and refined salt.

Oil

In the refineries the oil losses amount to appreciable quantities even though the estimated losses are between 0.5 and 3.0 per cent. Losses of this magnitude should impress the management so that they would make an effort to recover some of the profit that is getting away. Recording of the amount of flow of the wastes, together with continual sampling and routine analyses, will materially help management to determine the real extent of their manufacturing losses.

Modern, well designed, oil-water separators which handle only floating oils can produce effluents with oil concentrations of less than 10 p.p.m.

Waste Caustic

In the treatment of oils with alkaline compounds a series of alkaline wastes are produced which, though small in volume, are difficult to treat. Some of these wastes have high odor thresholds and B.O.D. values as high as 200,000 p.p.m. Some of the compounds can be removed by steam stripping or by the addition of chemicals. If these compounds are to be discharged to the sewer system, some method should be provided for leveling out the flow so that heavy concentrations are not discharged into the sewer at any one time. There are indications that the high B.O.D. of these wastes can be reduced by biological treatment.

Acid Sludge

The disposal of acid sludges should hardly be considered a waste problem. Some refineries no longer consider these materials as wastes because they are used as a source of recoverable acid and as fuel. The burning of the sludge may present considerable difficulty.

Emulsions

The emulsions formed in the water washing of acid-treated lubricating oils are very difficult to break. These waste waters usually contain up to 2 or 3 per cent oil, consequently they can not be discharged into the refinery sewer system. These emulsions must receive special chemical treatment if their formation can not be eliminated.

Segregation of Wastes

The oil refinery is an excellent example of an industry where the segregation of wastes is very important. If only one sewer system is available it means that large volumes of uncontaminated cooling water become polluted when discharged into the common sewer. In some cases it has been found desirable to have three sewer systems: (1) for sanitary sewage, (2) for storm and condenser water, and (3) for process water. When a refinery undertakes a plan as comprehensive as this, they then find it easier to treat the oil wastes in the special ways known to the industry.

Distillery and Alcohol Wastes

The final report of the Ohio River Committee (2) says, "The production of alcohol by fermentation and distillation is accomplished with the use of corn, rye, and malt for the production of whiskey; and molasses or cane syrup for the production of commercial or industrial rum and industrial alcohol."

In the manufacture of grain alcohol or whisky, the grain is milled, cooked, converted with malt, inoculated with yeast and fermented. The process for producing commercial alcohol is less complicated because all preparation of grain is eliminated. Sulfuric acid is added to the molasses to invert the sucrose to glucose and levulose before fermentation.

After fermentation the entire fermented mash or liquid is put through the stills. The whole stillage as it comes from the stills contains from 4 to 7 per cent total solids.

The simplest form of recovery has been described by Boruff (3) as being one where the stillage is first screened and the screenings pressed to remove more moisture. The two liquids are then combined and evaporated to a syrup containing 20 to 30 per cent solids. The concentrated syrup is mixed with the pressed grains and then dehydrated in rotary driers. If this or a similar process is used, practically all of the stillage, which has a B.O.D. of about 34,000 p.p.m., is kept from the sewers. There are usually 28 to 34 gal. of stillage per bushel of grain processed which must be disposed of in some manner. Not all distilleries have recovery processes, and if they do not, the stillage is sold to farmers, fed to cattle or used for irrigation.

The high organic content of any of the distillery wastes makes them very objectionable in any stream because of the high oxygen demand while undergoing decomposition. The high oxygen demand of the waste makes treatment by aerobic processes exceptionally expensive and troublesome for municipal sewage treatment plants.

Experimental studies have indicated that the wastes from distilleries can be treated by anaerobic fermentation with final treatment on trickling filters.

The Hiram Walker Plant in Peoria has demonstrated that a process for waste recovery can be carried out which will be satisfactory to the public and with operating expenses paid with revenue from the sale of by-products.

Summary

There are methods for eliminating industrial wastes. Some are now expensive and it will take the cooperation of all interested parties to make satisfactory industrial waste treatment and stream pollution abatement a reality.

References

1. Weston, R. F., "The Waste Disposal and Utilization Problems of the Petroleum Industry," *Proceedings* of the First Industrial Waste Utilization Conference, Purdue University, November 29–30, 1944, p. 98.
2. Final Report of the Ohio River Committee, Appendix VI of Supplement "D."
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THE USE OF THE DILUTION METHOD FOR DETERMINING THE EFFECT OF INDUSTRIAL WASTES ON DEOXYGENATION *

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Certain industrial wastes give a decreasing B.O.D. with increasing dilution. This has been referred to as the "sliding scale," and invalidates the B.O.D. determination. In some cases the difficulty from this source can be overcome by the use of a dilution water containing nitrogen and phosphorus. In other cases, however, this phenomenon is due not to a deficiency of nitrogen and phosphorous in the waste, but to the presence of certain toxic agents which exert an inhibiting effect on the deoxygenation of the waste at the higher concentrations.

The concentrations employed in the B.O.D. determination are determined by the B.O.D. of the waste. If the waste contains large quantities of oxidizable material in addition to some specific toxic ingredient, higher dilutions will have to be employed, which may or may not overcome the inhibition, depending upon the concentration and the potency of the toxic material. If the material has a low toxicity or is present in relatively low concentration, or if the oxidizable portion of the waste is relatively high, the dilution employed may completely obliterate the inhibition of the oxidation, and the B.O.D. will not manifest a decreasing value with increasing concentration. In such a case, although the B.O.D. values obtained from different dilutions will agree with one another, there is no guarantee that the same B.O.D. will be exerted in treatment processes or in the stream when such high dilutions are not available.

To investigate the deoxygenation rates of such wastes at lower dilutions, the B.O.D. method may be modified as follows: (*a*) by using pure oxygen to saturate the dilution water or (*b*) by pooling and reaerating the diluted samples of a given concentration of the waste during the incubation period. Even with these modifications, the range of concentration of the waste cannot be materially increased. The direct method of determining oxygen utilization described elsewhere (1) obviates all these difficulties and makes the use of any concentration of the waste possible.

When the concentration of the oxidizable material is low, and the concentration and potency of the toxic ingredient are high, then over the relatively low range of dilutions employed in the regular B.O.D. technique a decidedly lower B.O.D. will be obtained at the higher end of the concentrations. Although such a determination is of little value in regard to B.O.D., it has a definite diagnostic value in indicating the presence of toxic materials and the dilution necessary to overcome the toxicity.

The purpose of this paper is to draw attention to the possibilities and limitations in determining the B.O.D. of industrial wastes by the dilution method. The effect was studied of the addition of certain inorganic and organic materials, which may be present in industrial wastes, on the deoxygenation of sewage.

Method

Sewage was used as substrate in studying the effects of artificial addi-

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tions of chemicals. Various concentrations of the chemical were added to sewage and various dilutions made for B.O.D. determination, or a definite volume of sewage was added to the B.O.D. bottles together with different concentrations of the chemical. In the first method both the concentration of sewage and that of chemical were variable. In the second method the volume of sewage was such as to bring about appreciable, but not complete, depletion of the oxygen.

Effect of Chemicals on the Dissolved Oxygen Determination

It was necessary to test first the effect of the chemicals for a possible interference with the D.O. determination. This was accomplished by adding the various chemicals to the dilution water in different concentrations and

TABLE I.—Effect of Various Chemicals on the D.O. Determination

Chemical	Conc. (p.p.m.)	Winkler Method		Rideal-Stewart Modification	
		Blank (p.p.m.)	With Chemical (p.p.m.)	Blank (p.p.m.)	With Chemical (p.p.m.)
Ferric chloride	200	8.35	8.35	—	—
Alum	200	8.35	8.35	—	—
Ethylene dichloride	1,000	8.30	8.20	—	—
Gasolene	1,000	8.3	5.8	—	—
Gasolene	100	8.3	7.9	—	—
Kerosene	1,000	8.6	7.8	—	—
Kerosene	100	8.6	8.6	—	—
Ether	500	8.4	8.4	—	—
Methyl alcohol	1,000	8.4	8.4	—	—
Ethyl alcohol	1,000	8.4	8.4	—	—
Butyl alcohol	1,000	8.4	8.5	—	—
Amyl alcohol	1,000	8.4	8.4	—	—
Chloroform	1,000	8.4	8.4	—	—
Carbon tetrachloride	1,000	8.4	8.4	—	—
Toluene	1,000	8.5	8.4	—	—
Xylene	1,000	8.5	8.4	—	—
Benzene	1,000	8.4	8.4	—	—
Formaldehyde	1,000	8.1	7.4	—	—
Formaldehyde	100	8.1	8.1	—	—
Acetone	1,000	8.1	7.5	—	—
Acetone	100	8.1	8.3	—	—
Sodium arsenite	50	8.2	2.6	8.2	8.0
Sodium arsenite	33	8.2	4.7	8.2	8.1
Sodium arsenite	17	8.2	6.5	8.2	8.2
Sodium arsenite	8	8.2	7.6	8.2	8.3
Potassium cyanide	50	8.2	8.0	8.2	8.1
Potassium cyanide	33	8.2	8.5	8.2	8.2
Potassium cyanide	17	8.2	8.5	8.2	8.4
Sodium arsenite	100	8.5	8.5	—	—
Potassium dichromate	100	8.5	18.0	8.5	18.0
Potassium chromate	100	8.5	15.4	—	—
Potassium chromate	25	8.5	10.5	—	—
Potassium chromate	10	8.5	9.2	—	—
Mercuric bichloride	100	8.4	8.3	—	—
Cobalt chloride	100	8.4	8.4	—	—
Copper sulfate	100	8.4	8.5	—	—
Phenol	100	8.35	6.95	—	—
Phenol	50	8.35	7.45	—	—
Phenol	10	8.35	8.05	—	—
Strychnine	100	8.5	7.5	—	—
Brucine	100	8.5	8.2	—	—

determining immediately the dissolved oxygen. In the majority of cases, only the Winkler method was used. When there was an interference the Rideal-Stewart modification was also used in order to eliminate the interference if possible. The results were compared with the D.O. of the dilution water without the chemical. In Table I, the results of these determinations are assembled. Serious interference was encountered with gasolene, phenol, sodium arsenite, potassium dichromate, potassium chromate, and strychnine. The magnitude of the interference varied with the concentration of the chemical.

The interference from sodium arsenite could be overcome by the Rideal-Stewart modification, provided sufficient permangenate was added. In several instances difficulty was encountered in the titration stage with sodium thiosulfate, due to the recurrence of the blue color after starch addition.

On the basis of the above results those chemicals that showed little interference or in which the interference could be overcome by suitable modification were selected for the study of the effect on deoxygenation. Phenol and gasolene, which showed an initial depression of the dissolved oxygen level, were studied by using the initial blank containing the various concentrations of the chemicals for comparison with the results after incubation. Only some of the suggestive results are incorporated in this paper for the purpose of illustration.

Inorganic Poisons

The effects of a number of inorganic poisons were studied. Various concentrations from 100 to 0 p.p.m. were added to B.O.D. bottles, each containing 20 c.c. of sewage and diluted with sodium bicarbonate water. Dissolved oxygen determinations were made initially and at the end of 5 days.

The results are plotted in Figure 1 as parts per million O_2 utilized in 5

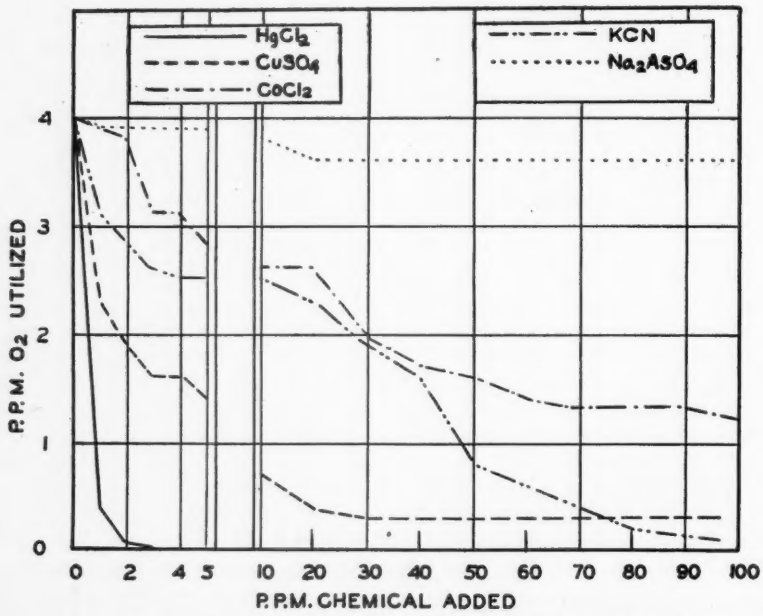

FIGURE 1.—The effect of various concentrations of chemicals on the 5-day oxygen utilization of sewage as determined by the dilution method.

days against the various concentrations of the chemicals. The results are to be compared with the oxygen utilized by the sewage without the chemicals. Sodium arsenate up to 100 p.p.m. had only slight effect on oxygen utilization. Potassium cyanide, on the other hand, depressed the oxygen utilization sharply even with extremely low concentration; for instance, 5 p.p.m. produced 38 per cent inhibition, and 50 p.p.m. resulted in 80 per cent inhibition. Oxygen utilization was negligible with 100 p.p.m. of potassium cyanide. Cobalt chloride gave results similar to potassium cyanide except that the inhibition was not quite so pronounced. Copper sulfate caused a very sharp depressing effect even at low concentrations, amounting to 80 per cent reduction in oxygen utilization with 10 p.p.m. These results were obtained despite the precipitation of copper by the bicarbonate in the dilution water. The effect of mercuric bichloride was the most striking. Oxygen utilization with 1 p.p.m. was reduced by 90 per cent and with 3 p.p.m. it was completely inhibited.

The effect of sodium arsenite was studied by adding 500 p.p.m. to sewage and introducing various volumes of the treated sewage into B.O.D. bottles and diluting it with seeded mineral dilution water. D.O. values at the beginning and after 5 days as determined by the Rideal-Stewart modification are given in Table II. The concentrations of the arsenite refer to the ultimate concentration after dilution in the B.O.D. bottles. The B.O.D. values are calculated from the respective depletions and concentrations of sewage. A 50 per cent lower B.O.D. value was obtained with 50 p.p.m. of sodium arsenite than with 4.0 p.p.m. The B.O.D. values of the sewage increased with decreasing concentrations of the chemical.

TABLE II.—Effect of Sodium Arsenite on the Oxygen Utilization Rate of Sewage*

Conc. (p.p.m.)	D.O. Initial (p.p.m.)	D.O. After 5 Days (p.p.m.)	B.O.D. (p.p.m.)
50	8.0	2.4	56
33	8.1	4.2	58
17	8.2	5.7	75
8	8.3	6.9	84
4	8.3	7.35	114

* Incubation period 5 days.

Phenol

Phenol concentrations above 2 p.p.m. completely depleted the dissolved oxygen in 5 days, and even with daily poolings and reaerations of the samples more than 5 p.p.m. phenol depleted the dissolved oxygen in 24 hours, so that the effect of higher concentrations of phenol could not be studied by this method. Results obtained by the direct method of oxygen utilization have been reported elsewhere (1). It was found by the latter method that phenol even up to 1,000 p.p.m. concentration had an ultimate oxygen demand, although the rate of utilization was retarded initially.

Gasolene, Kerosene, Alcohols

Gasolene, kerosene, ethyl, methyl, butyl and amyl alcohols above 0.1 c.c. per liter in concentration depleted completely the dissolved oxygen in 5 days. The results obtained with 0.05 c.c. per liter or less are given in Table III. Equal quantities of sewage were distributed into a number of bottles. Various quantities of the above organic materials were introduced and diluted with sodium bicarbonate dilution water. The immiscible materials were emulsified with a hand emulsifier prior to addition. The depletions are expressed, first, on the basis of mixture of sewage and chemical; then by subtracting the demand exerted by the sewage, the depletions and B.O.D.'s of the chemical are derived. The assumption was made that the oxygen demand exerted by the sewage in the presence of the chemical was the same as by the sewage alone. That this assumption

TABLE III.—Effect of Certain Organic Materials on Oxygen Demand of Sewage*

Chemical	Concentration (c.c./liter)	Chemical and Sewage Depletion (p.p.m.)	Chemical Alone Depletion (p.p.m.)	B.O.D. (mg./c.c.)
Gasolene	0.05	6.5	4.3	86
	0.025	4.3	2.1	84
	0.020	3.8	1.6	80
	0.015	3.2	1.0	66
	0.010	2.9	0.7	70
	0.005	2.6	0.4	80
	0.0025	2.4	0.2	80
	0	2.2	—	—
Average				78
Kerosene	0.015	8.1+	—	—
	0.010	7.0	4.8	480
	0.005	5.0	2.8	560
	0.0025	3.6	1.4	560
	0.001	2.5	0.3	—
	0	2.2	—	—
Average				533
Ethyl alcohol	0.010	8.2+	—	—
	0.005	7.5	5.1	1,020
	0.0025	5.1	2.7	1,080
	0.001	3.5	1.1	1,100
	0	2.4	—	
Average				1,070
Methyl alcohol	0.010	8.2+	—	—
	0.005	6.0	3.6	720
	0.0025	4.4	2.0	800
	0.001	3.0	0.6	—
	0	2.4	—	—
Average				760
Butyl alcohol	0.005	8.2+	—	—
	0.0025	6.4	4.0	1,600
	0.001	3.7	1.3	1,300
	0	2.4	—	
Average				1,450
Amyl alcohol	0.005	8.2+	—	—
	0.0025	5.1	3.0	1,200
	0.001	3.1	1.0	1,000
	0	2.1	—	
Average				1,100

* Incubation period 5 days.

was justified is shown by the good agreement obtained for the B.O.D. values of the chemicals with different concentrations.

The results indicate that gasolene at all the concentrations employed increased the oxygen demand of the sewage. The B.O.D. of the gasolene varied from 66 to 86 mg. per c.c. with an average of 78. There is no indication of decreasing B.O.D. values with increasing concentrations of gasoline, which means that within this range gasolene did not exert an inhibiting action.

Kerosene, when added at a concentration of 0.015 c.c. per liter, completely depleted the dissolved oxygen content of the mixture, indicating that it exerts a higher oxygen demand than gasolene. The B.O.D. values of kerosene varied from 480 to 560 mg. per c.c., with an average of 533 mg. per c.c. The oxygen demand of kerosene is nearly 7 times greater than gasolene, but it falls in the same category in that it has no deleterious effect on oxygen utilization within this narrow range of concentrations.

Similarly, ethyl alcohol has an even higher oxygen demand, and no retarding effect on oxygen utilization within the narrow range of concentrations in which dissolved oxygen could be maintained. The oxygen demand of methyl alcohol is somewhat lower than that of ethyl alcohol, while that of butyl alcohol is higher. Amyl alcohol has an average oxygen demand of 1,100 mg. per c.c. These materials, therefore, fall into a group varying in their oxygen demand but having no effect on oxidation rates within the narrow range of concentrations which could be employed in the dilution method of B.O.D. determinations. Their effect at higher concentrations cannot be determined by this method.

Other Organic Substances

The effects of another group of chemicals, namely, carbon tetrachloride, toluene, xylene, benzene, chloroform, ethylene chloride, acetone, formaldehyde, and ether, are given in Table IV and differ greatly from these grouped

TABLE IV.—Effect of Various Chemicals on Oxygen Depletions (P.P.M. in 5 Days)

Conc. (c.c./liter)	Carbon Tetrachloride	Toluene	Xylene	Benzene	Chloroform	Ether	Acetone	Formaldehyde	Ethylene Chloride
1.0	0.5	0.6	0.6	1.4	8.4+	8.4+	8.2+	—	4.0
0.5	0.7	0.7	0.6	8.4+	6.1	8.4+	8.2+	—	3.1
0.25	0.7	8.4+	8.4+	8.4+	4.4	8.4+	—	—	2.5
0.1	1.3	8.4+	8.4+	8.4+	2.9	5.1	5.9	—	2.2
0.05	1.6	8.4+	8.4+	8.4+	2.6	3.6	6.1	—	2.3
0.025	1.9	8.4+	8.4+	8.4+	2.7	2.9	5.5	—	—
0.01	1.9	8.4+	8.4+	8.4+	2.1	2.4	5.2	5.2	2.0
0.005	1.9	—	—	—	2.2	2.3	—	3.9	—
0.0025	1.9	—	—	—	2.1	2.2	—	2.9	—
0.001	2.0	—	—	—	2.1	2.5	—	2.3	—
0	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.2

in Table III. The concentrations employed are much higher than in the former group and the effects are much less pronounced. With various concentrations of carbon tetrachloride the oxygen utilization was lower than by sewage alone, indicating that this material exerts no oxygen demand of its own but instead inhibits the oxidation of sewage. Toluene, xylene, and benzene fall into a group in which the addition of 1 c.c. per liter showed some oxygen utilization which was lower than the control, but with concentrations as low as 0.0025 c.c. per liter all the oxygen was depleted, showing an oxygen demand greater than the dissolved oxygen content of the dilution water. Chloroform depleted completely the dissolved oxygen when added in concentration of 1 c.c. per liter, and ether likewise depleted the oxygen at 0.25 c.c. per liter concentration. With lower concentrations the oxygen depletions decreased but were not lower than the control, indicating that little inhibiting action was exerted. Acetone also increased the oxygen demand of sewage. Formaldehyde, in the low concentrations employed, increased the oxygen utilization.

Carbon tetrachloride, therefore, does not have a B.O.D., since the oxygen demand exerted in its presence is lower than the oxygen demand of sewage. The B.O.D. of toluene, xylene and benzene cannot be calculated from the results at hand since in the concentrations employed these substances depleted the dissolved oxygen completely. The B.O.D. of the rest of the materials can be calculated by assuming that the oxygen demand of the sewage was not affected by the presence of the chemicals.

The results given in Table V indicate that chloroform and ether have a small oxygen demand. Within the range of concentrations used, the B.O.D.'s do not exhibit decreasing values and, therefore, have not exerted an inhibiting influence. The oxygen demand of these materials is lower than those given in Table III.

Acetone exhibits definitely increasing B.O.D. values with lower concentrations. Formaldehyde, at the concentrations used, had an appreciable and

TABLE V.—Calculated 5-Day B.O.D. Values of Materials

Conc. (c.c./liter)	Chloroform (mg./c.c.)	Ether (mg./c.c.)	Acetone (mg./c.c.)	Formaldehyde (mg./c.c.)	Ethylene dichloride (mg./c.c.)
1.0	—	—	—	—	1.8
0.5	8.0	—	—	—	1.8
0.25	9.2	—	—	—	2.0
0.1	8.0	30	38	—	—
0.05	10.0	30	80	—	—
0.025	—	32	136	—	—
0.01	—	30	310	310	—
0.005	—	—	—	360	—
0.0025	—	—	—	320	—
0.001	—	—	—	—	—

constant B.O.D. Ethylene chloride had an extremely small B.O.D. value.

Discussion

The results indicate the limitations and possibilities in the use of the dilution method of B.O.D. for assaying the toxic properties of industrial wastes. With inorganic inhibiting agents, which have no oxygen demand of their own, it is a simple matter to use a suitable well-seeded organic substrate, to add various concentrations of the toxic chemical, to dilute with well oxygenated mineral dilution water, and to determine the oxygen utilization over suitable periods of time.

Domestic sewage serves as a good substrate for such a study. It is only necessary that the volume used should bring about sufficient depletion of oxygen. If too much sewage is used, the oxygen will be completely depleted, with the result that the effect of the chemical agent added cannot be accurately estimated. If the volume of sewage is too small, then the effect of chemicals on oxygen depletions cannot be evaluated with precision on account of the narrow range of depletions.

The chemical should be added after the sewage is diluted, in order to prevent a temporary high concentration with its inhibiting influence. Furthermore, the chemical itself should not interfere with the D.O. determination.

The effects of various concentrations of the chemical on oxygen utilization rates over a period of at least twenty days could be studied, but this would be very laborious. However, if a fixed volume of sewage were used to cover the entire period of study, it would cause too little depletions and result in less accuracy for the shorter periods. Changing the volume of sewage according to the length of incubation would introduce objectionable variables.

The results presented with such inorganic poisons for a 5-day period of incubation are suggestive of the possibilities of the use of this method for evaluation of the toxic concentrations. The possibility of adaptation by selection and cultivation of a specialized flora tolerating the initial toxic concentrations cannot be readily studied.

Organic wastes with an oxygen demand at low concentrations and an inhibiting effect at higher concentrations offer additional difficulties, and preclude the possibility of studying such effects over a wide range of concentrations. By pooling and reaerating the B.O.D. bottles during the incubation period, before complete depletion, the range of concentrations may be somewhat extended. Caution should be exercised when dealing with solvents by this technique, as losses would occur during reaeration, causing an error. Dilution water saturated with oxygen gas may also serve this purpose.

Over the narrow range of concentrations that could be employed by this method, some interesting observations were made. There were only a few organic materials which did not exert an oxygen demand. Even materials which are commonly employed for inhibition of microbial activity had some oxygen demand. This emphasizes the concept that toxicity is relative and is a function of concentration. A material may be toxic at higher concentrations and oxidizable at lower concentrations. The method lends itself only to the lower and oxidizable concentrations and is not applicable to the higher and toxic range.

The only substance in this study which did not exert any oxygen demand was carbon tetrachloride. The ability of microorganisms to utilize hydrocarbons has been studied by many investigators. Zobell (2) has reviewed the available literature.

On the basis of their effects on oxygen utilization within the range of concentration employed the organic materials tested may be grouped under the following categories:

(1) Those with a high oxygen demand, but no apparent toxic effect; examples: kerosene, ethyl alcohol, methyl alcohol, butyl alcohol, and amyl alcohol. The lack of toxicity is suggested by the absence of the decreasing B.O.D. values with increasing concentrations.

(2) Those having an oxygen demand at low concentrations and a toxic effect at higher concentrations; examples: acetone, toluene, xylene, benzene.

(3) Those without any oxygen demand but with a toxic effect; example: carbon tetrachloride.

(4) Those having a slight oxygen demand and low toxicity; examples: chloroform, ether, ethylene chloride.

(5) Those with low oxygen demand, but no toxicity; example: gasolene.

It should be emphasized that the grouping of the chemicals in these categories applies only within the range of concentrations which the method permitted, and may be subject to change with another method in which higher concentrations can be studied.

The possibility of increasing the B.O.D. of sewage by using preservatives such as chloroform and formaldehyde is indicated.

Mixed organic wastes of unknown character have been studied by this method, but no reliable results over a wide enough range of concentrations could be obtained. Despite attempts to reaerate the oxygen at times became completely depleted, thus invalidating the results.

The many difficulties in obtaining reliable results on B.O.D. values of some industrial wastes are recognized. The difficulties can be made use of in detecting the presence of inhibiting agents, determining the dilution necessary to overcome the inhibition, and in preparing the material for suitable biological treatment. When such dilution is reached and used in the B.O.D. determination, the results should be fairly constant. The range which produces decreasing B.O.D. values would indicate the inhibiting zone, and the lower concentrations with constant B.O.D. values would indicate the true oxygen demand. This is because, without such dilution, biological treatment is not practical, and in a majority of cases a dilution high enough to permit biological action is obtained in the receiving stream. When the wastes consist of inorganic materials alone, then the B.O.D. determination is needless, but the B.O.D. technique can be used to assay the effect of such wastes when they become mixed with oxidizable organic materials.

Summary and Conclusions

The effect of inorganic substances on the oxygen utilization can be studied readily by introducing various concentrations of the compounds into a suitable volume of sewage after dilution. Toxicity is indicated by decreasing oxygen utilization with increasing concentrations. The study of the effect of organic substances is subject to the limitation imposed by the low concentrations that can be employed by the dilution method, since most of the organic compounds have an oxygen demand. Even materials used as preservatives are oxidized at low enough concentrations.

The B.O.D. of these organic materials can be determined by subtracting the oxygen demand of the sewage from the total utilized. However, the B.O.D. thus determined applies only to the concentrations employed. If it were possible to use higher concentrations, a different value might be obtained. Many organic substances are oxidizable at low concentrations and toxic at high concentrations; that is, they have an oxygen demand at low concentrations and not only remain unoxidized at higher concentrations, but also retard the oxidation of an otherwise oxidizable substrate, such as sewage. Thus within only a narrow range can these effects be studied by the di-

lution method. The same difficulties are encountered when an attempt is made to appraise the B.O.D. of mixed unknown wastes containing both an oxidizable organic material and an inhibiting agent. By the direct method, the oxygen utilization over any range of concentrations can be studied.

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PONDING OF SULFATE PAPER MILL WASTES

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Wastes from modern sulfate mills are such that in many cases where appreciable volumes of dilution water are available, little effect on the receiving stream is observed. This is due to the fact that chemical recovery is the very essence of the kraft pulping procedure. The spent cooking liquor is recovered as an integral part of the process. Due to advances in mill design, equipment and operation the losses from such mills are usually not large.

Situations do exist, however, where stream flows are periodically low, or a tidal effect exists, when serious pollution problems occur. There are also cases where adequate dilution is available but thorough mixing is difficult to obtain. This condition results in certain polluted zones in the stream. Finally, there are instances when strong wastes are periodically discharged due to shutdowns, clean-up periods, spills and process changes. Such periods may overtax the limits of streams which receive the normal effluents without detriment, and undoubtedly cause grave aggravation where problems already exist. This latter condition is particularly significant as it is extremely difficult, if not impossible, to control all such possible losses. Also, per unit of wastes, those from the sulfate process are more toxic than wastes resulting from other methods of pulping.

Dr. Ellis has pointed out that a fish can only be killed once, in emphasis of the fact that a single input of strong wastes can undo all the efforts of a mill to reduce continuous losses, as far as the stream pollution picture is concerned. Lagooning, or ponding, of these wastes may be of considerable interest to sulfate pulp mills located where areas of waste land are available. Even where long retention periods may not be realized this method of handling the waste problem may be advantageous due to the equalizing effect of storage, which is capable of reducing or even eliminating the effects of short periods of strong waste discharge.

Five forms of ponding are in general practice for the disposition of liquid wastes. These are as follows:

1. Lagoons providing short periods of detention to allow the separation of suspended solids prior to discharge.
2. Lagoons providing detention of strong wastes over a considerable period of time to control admission to the receiving stream in relation to the flow of water available for dilution.
3. Ponding of all waste waters in reservoirs for a sufficient time to allow natural processes of purification to reduce the pollutional characteristics of the wastes.
4. The storage of wastes in conjunction with a biological treatment device through which the stored water is recycled repeatedly until purified to the desired degree.
5. Ponding of wastes supplemented with addition of chemicals, such as sodium nitrate, which in supplying oxygen and nitrogen in acceptable form will enhance oxidation by aerobic micro-organisms.

As the mill involved in the studies reported in this paper has employed storage and regulated discharge of the stronger wastes (method No. 2 above), the following discussion is concerned with results obtained by this type of ponding procedure.

Definition of Problem

The mill of the Camp Manufacturing Company, Inc., is located on the Blackwater River at Franklin, Va. This is a small fresh water stream which finally terminates in the Albemarle Sound.

A tidal effect exists below the mill and for several miles upstream. Normally this effect is quite small but is varied greatly by prevailing wind conditions.

The flow of the Blackwater is highly variable, being exceedingly small (under 200 c.f.s.) during a considerable portion of the summer months and attaining discharges of 1,000 to 2,000 c.f.s. during the winter period. Also, during the summer the river temperatures range from 75° to 85° F., which is from 35° to 45° F. higher than winter temperatures. This results in a greater reactivity of the wastes and further accentuates the pollution problem.

It has been the practice of the company since 1939 to conduct periodic surveys, at least weekly, along the course of the Blackwater River to determine the existing conditions of the stream. Using the station at Burdette, Va., which is about 10 miles upstream from the site of the mill, as a criterion of natural river characteristics, it is not at all unusual to obtain dissolved oxygen contents of under 5 p.p.m. during the summer months. Certain factors greatly affect this condition. The most important of these is the tremendous natural pollution load which enters the Blackwater in its course through swamp-fed territory. Secondly, some cognizance should be taken of the input of domestic and farm sources of pollution which empty untreated into the river. Also, of course, this condition is largely due to the inherent nature of the stream as a relatively deep, sluggish, and slow flowing river.

Mill Wastes

The total wastes from the mill amount to approximately 8 m.g.d., resulting from unbleached sulfate pulping operations and the manufacture of kraft paper.

Originally all of these wastes emptied into the Blackwater River. The original condition of the stream has been changed by the development of a selective ponding procedure.

Development of Ponding System

The problem was attacked from the standpoint of segregating certain of the wastes for ponding. This approach was predicated on the assumption that some of the mill waters, while low in volume, possessed high polluting characteristics. Then the worst offenders from a pollution standpoint were separated from the other waste waters and impounded in a pond built for this purpose so that these wastes did not enter the river in the summer. The pond was then emptied gradually to the river during periods of high stream flow conditions and low water temperatures. No detrimental effects have been experienced in following this procedure. Last year a 20 per cent drop in dissolved oxygen occurred from upstream levels but the concentration did not drop below 9.0 p.p.m. at the point of greatest depletion during the pond emptying process. At this time, in December, the average flow was approximately 400 m.g.d. and the prevailing water temperature was 37° F.

The ponded fraction was increased gradually until in 1945 it amounted to about 500 g.p.m. At that time it was composed of the final pulp washing water, digester blow-down condensate, turpentine separation decanter overflow and impurities from the dregs washer of the causticizing operation. This fraction, amounting to about 10 per cent of the total waste flow, was calculated to contribute approximately 40 per cent of the total mill pollution load. Therefore, the ponding system was accomplishing a 40 per cent decrease in total load resulting from mill operations during the summer months.

This load was then added when stream conditions were more favorable.

Results

Work was also done to obtain some basic evaluation of the worth of the ponding system from the viewpoint of a partial oxidation treatment process. Samples were taken which afforded a comparison between the pond influent and the pond effluent after a 4-month ponding period. Averages of twenty analyses on both types of samples gave results (Table I) which prompt the following conclusions:

1. The oxygen demand, as measured by permanganate consumption, is decreased 35.2 per cent by ponding.
2. The pH drops from 11.0–11.5 to 8.5–9.0.
3. Five-day B.O.D. tests showed a decrease of 21.8 per cent.
4. Total suspended solids decreased 81.1 per cent.
5. Total dissolved solids decreased 17.4 per cent.
6. Total solids decreased 21.7 per cent.

TABLE I.—Comparison of Pond Influent and Pond Effluent Samples
(All results in p.p.m.)

Determination	Pond Influent	Pond Effluent
Oxygen Consumed		
Maximum	3,100	1,900
Minimum	1,400	800
Average	2,120	1,375
5-Day B.O.D. (20° C.)		
Maximum	862	782
Minimum	342	402
Average	648	507
Total Suspended Solids		
Maximum	324	64
Minimum	112	21
Average	122	42
Total Dissolved Solids		
Maximum	4,452	2,736
Minimum	1,902	2,522
Average	3,163	2,612
Total Solids		
Maximum	4,739	2,772
Minimum	2,079	2,563
Average	3,385	2,654

A main factor in considering the worth of ponding as a treatment system is not shown in these results. This is the fact that these materials are collected during periods of high water temperatures and low flow and are discharged under conditions of much lower water temperature and high stream flow, thus greatly decreasing the effects of the wastes on the river.

These data are presented as being representative only of existing conditions, and to illustrate expectancy of the ponding procedure. Mill changes are constantly in progress which may change the volumes and specific character of the individual wastes, but should not disturb the observed trends.

Such a case has occurred during the past year when a further enlargement of the ponded fraction has taken place. In consideration of the 60 per cent of the total load entering the river even with the operation of the existing ponding system, extensive mill surveys were undertaken to determine the possibility of reducing this load by further additions to the pond influent. This work involved studies of the mill operations and wastes produced that contributed to the flow of the main plant sewer discharging to the river. The results are given in Table II and in the accompanying discussion.

TABLE II.—Volume and 5-Day B.O.D. of Various Mill Wastes

	Paper Mill	Pulp Mill	Barometric Leg	Evaporator Condensate
Max. B.O.D. (p.p.m.)	137	365	62	636
Min. B.O.D. (p.p.m.)	5	132	10	596
Ave. B.O.D. (p.p.m.)	74	237	39	601
Flow (m.g.d.)	1	1	3	1/3

1. *Paper Mill Effluent.* This waste comprises 14 per cent of the flow of the main sewer and contains 8.3 per cent of its pollution load. It is mainly objectionable from a fiber loss standpoint and strict control of this factor has been maintained.

2. *Pulp Mill Effluent.* This effluent is the greatest single polluting component of the main sewer flow. It is quite variable, reflecting any difficulties in the pulp refining operations. The waste amounts to 14 per cent of the main sewer flow and contributes 26.6 per cent of the pollution load.

3. *Barometric Leg Effluent.* This water is used for maintaining the vacuum on the evaporators. It amounts to about 45 per cent of the main sewer flow but contributes only 13.1 per cent of the pollution load. The flow amounts to about 3 m.g.d. and the average B.O.D. was 39 p.p.m. This waste is significant from a pollution standpoint mainly because of its large volume and objectionable odor.

4. *Evaporator Condensate Effluent.* This waste from the evaporation process amounts to only 5 per cent of the main sewer flow but contributes a pollution load of 22.4 per cent of the total load discharged by the main sewer. Further, it is easily contaminated by evaporator imbalance. The flow is approximately 0.3 m.g.d. and the average B.O.D. was 601 p.p.m. Here, obviously, is a waste representing a pollution load far out of proportion to its volume, and plans were immediately carried through to remove it from the main sewer and add it to the fraction being ponded.

5. *Miscellaneous Effluents.* Under this heading must be included all of the floor drains, cooling water, spills and leaks that occur in the mill. Taken all together such sources are of considerable importance in the pollution picture. They are so varied that even though constant surveillance is maintained a complete means of control within the mill is impossible. It is estimated that such sources normally contribute about 30 per cent of the pollution load and 25 per cent of the main sewer flow.

Present Situation

Following the addition of the evaporator condensate to the ponded fraction, work was undertaken during the summer of 1946 to determine the improvement in accomplishment of the ponding system. An intensive study was also made of river conditions and mill operations to discover any errors or disadvantages in the ponding procedure.

Ponding was started on April 25, 1946, with satisfactory river conditions prevailing at that time. With May as the first full month of ponding, fifty individual analyses of mill wastes, at least one daily, showed that 61 per cent of the total plant pollution load was ponded. Similarly, 44 analyses in June and 49 in July showed that 62 and 59 per cent, respectively, of the load was ponded in those months.

Therefore, in terms of the pollution load brought under control, the effectiveness of the procedure was increased from 40 per cent to 60 per cent by the ponding of the added flow of evaporator condensate. Practically, this means that without the ponding operation, 2½ times as great a pollution load would enter the river. The remaining fraction which does travel directly to the river, however, still presents an unsatisfactory picture due to several inherent inadequacies in present ponding practice. These fall in the category of abnormal losses as occur during operational difficulties, and they greatly increase the load going directly to the river.

Proposed Expansion of Ponding Operations

In an effort to correct these shortcomings, studies were undertaken to determine the feasibility of ponding the total flow of mill wastes. This

phase of the work was a direct outgrowth of that undertaken in evaluating the worth of the existing ponding system as a partial treatment process, as outlined above. Inasmuch as some improvement was accomplished in ponding the concentrated wastes, the idea evolved of studying the effects on the much weaker wastes traveling directly through the main sewer to the river if they could be impounded for several weeks' time. The whole basis for this idea is the segregation of the wastes into two fractions.

The present pond influent fraction is relatively small in volume—12.5 per cent of the total—but carries 60 per cent of the total load. The present main sewer flow is relatively weak in concentration but large in volume. If the two are mixed initially the resulting combination is too concentrated to accomplish desired results through natural oxidation during ponding. It must be realized that the concentrated fraction is being ponded for a long time to await adequate stream conditions, while the larger and less concentrated fraction is to be submitted to temporary natural oxidation before entering the stream.

In practice this procedure would involve pumping the entire present main sewer flow to a ponding area that has already been constructed. The flow of this sewer amounts to approximately 50 million gallons a week, and with the available storage of 175 million gallons capacity, a retention period of three weeks could be realized. The pond influent, or concentrated fraction, would continue to be pumped into a separate ponding area as at the present time.

Considering the primary object of bettering the present main sewer wastes, this procedure has several points to recommend it. Mill water from all sources—whether during normal or abnormal periods, good or bad operation, starting up or shutting down the mill—would go directly to the swamp area. During this period of retention in the swamp the following things would occur:

1. Obviously, the higher temperatures of the wastes leaving the mill would be reduced to atmospheric temperatures, which in itself would reduce their biochemical activity.

2. Fiber and other suspended solids would be deposited before reaching the river. A settling basin ahead of the main lagoon is planned for this purpose. Such an installation could be readily cleaned if necessary.

3. The final outflow would be a relatively homogeneous and partially stabilized mixture rather than the variable concentration which exists at the present time.

Laboratory Studies

For the purpose of laboratory observation of the changes that would take

TABLE III.—Average Results of Laboratory Storage on 20 Samples Representing "Normal" Operation

Storage Time (weeks)	Reducing Substances[1]	pH	5-Day B.O.D. (p.p.m.)	Methyl Orange Alkalinity[2]
0	7.7	8.5	109	3.6
1	2.2	7.3	44	3.6
2	2.3	8.0	22	3.9
3	2.2	8.2	16	4.3

[1] Expressed as ml. N/40 I_2.
[2] Expressed as ml. N/10 HCl per 100 ml. sample.

TABLE IV.—Average Results of Laboratory Storage on High Fiber Loss Wastes[1]

Storage Time (weeks)	Reducing Substances[2]	pH	5-Day B.O.D. (p.p.m.)	Methyl Orange Alkalinity[3]
0	4.8	7.9	149	3.0
1	1.6	7.1	48	2.8
2	1.5	7.5	38	3.3
3	1.4	7.7	39	4.2

[1] Two samples, one containing 500 p.p.m. and the other 1,500 p.p.m. of suspended solids.
[2] Expressed as ml. N/40 I_2.
[3] Expressed as ml. N/10 HCl per 100 ml. sample.

TABLE V.—Behavior During Storage of Three Samples of High Chemical Loss Wastes

Sample No.	Storage Time (weeks)	Reducing Substances[1]	pH	5-Day B.O.D. (p.p.m.)	Methyl Orange Alkalinity[2]
1	0	132	10.8	1,450	38
	1	196	9.6	1,525	—
	2	96	9.2	1,425	34
	3	124	9.1	1,550	52
2	0	72	10.4	595	16
	1	124	9.0	415	18
	2	60	8.2	300	26
	3	72	8.6	255	—
3	0	64	10.5	725	19
	1	76	9.2	725	17
	2	64	8.1	205	20
	3	96	8.7	255	23

[1] Expressed as ml. N/40 I_2.
[2] Expressed as ml. N/10 HCl per 100 ml. sample.

place during storage of the present main sewer flow, samples were taken and grouped into three categories. It was desired to observe separately the effects of storage on, first, samples collected during so-called "normal" operation (Table III); second, samples taken during periods of high fiber loss (Table IV); and, third, samples representing periods of high chemical loss (Table V).

Observations of Normal Operation Samples (Table III):

Reducing substances, as indicated by the iodine demand, are reduced about 70 per cent on standing. Before the end of the 3-week storage period these samples became odorless. The residual reducing substances are evidently nonvolatile in nature.

The pH during storage underwent an initial drop and a gradual return to normal. This behavior is most likely due to bacterial activity. During the test period considerable evaporation took place at the prevailing laboratory temperature of 80° to 90° F.

The 5-day B.O.D. showed a 60 per cent drop after 1 week, 80 per cent after 2 weeks, and 85 per cent after the third week.

Preliminary tests indicate that the stored samples of wastes contain appreciable dissolved oxygen at the conclusion of the tests, and exhibited no toxic effects upon fish when diluted with only five volumes of water.

Observations of High Fiber Loss Samples (Table IV):

The high fiber loss samples behaved similarly during storage to the normal operation waste samples, indicating that the fiber is not a strong immediate pollution agent. The B.O.D. reduction of 75 per cent after three weeks is not as great as the average taking place in the normal operation samples, but is comparable to certain individual ones. These samples became odorless very rapidly.

There was a 68 per cent decrease of reducing substances in the first week, and a final reduction of 71 per cent after three weeks storage.

Observation of High Chemical Loss Samples (Table V):

Observation of these samples indicates the desirability of maintaining these wastes in as dilute an original condition as possible. It will be noted that sample No. 1 was so concentrated that the storage period was of no value. In the other two samples, definite improvement occurred, but the end result was still not acceptable.

This observation is used as a basis for the segregation of the strong wastes into a separate pond and the retention of the more dilute wastes by themselves.

Field Studies Planned

It is contemplated that the complete ponding program can be put into effect in 1947. It should be noted that the last phase of this work is based on laboratory studies entirely. Certain difficulties are expected in transferring

this idea to actual practice because of the large volumes involved. There appears to be sufficient merit in the plan, however, to justify every effort to place it into operation.

During the course of these investigations certain questions have arisen as to the reasons for the behavior of the segregated fractions. Therefore, together with the work entailed in actually placing the system into operation, research studies concerning the effects of varying concentrations of the different effluents on the efficiency of the natural oxidation process will be continued.

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REACTION OF SODIUM NITRATE IN STABILIZING ORGANIC WASTES

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Recently two publications (1) (2) have called attention to a very old reaction in which nitrate, usually in the form of sodium nitrate, reacts with oxidizable organic matter to produce a degree of stability proportional to the amount of sodium nitrate added.

This reaction was formerly employed to determine what was known as the nitrate oxygen demand of waste liquors (3). In the first two articles referred to, the amount of available oxygen is calculated on the assumption that all three oxygens of the nitrate molecule are available for oxidation. The authors make no claim for chemical justification of this method of calculation and have frankly arrived at their figure by purely empirical means (4). The reaction as described in the Sixth Edition of "Standard Methods," page 79 (*loc. cit.*), indicates that the nitrate oxygen demand was calculated on the assumption that 2½ atoms of oxygen were available for oxidation, and that the nitrogen is reduced to N_2 according to the equation

$$C + 2\ NaNO_3 = Na_2CO_3 + N_2$$

where "C" is used as typical of any oxidizable organic matter.

The writer wishes to call attention to the fact that under anaerobic conditions the nitrogen can be reduced to ammonia according to the following reaction:

$$2\ C + NaNO_3 + 3\ H_2O = NaHCO_3 + NH_4HCO_3$$

According to this reaction 2½ oxygens from the sodium nitrate plus 1½ oxygens from the 3 molecules of water are used in oxidizing 2 C to 2 CO_2.

Some early experiments carried on in this laboratory (5) indicate that this latter reaction actually does occur, and many subsequent experiments reported in later publications of the Illinois State Water Survey have failed to show any evolution of N_2 from nitrates.

While empirical methods are useful, it is believed that a further study of this reaction will be worth while, especially when it is considered that sodium nitrate at even $35 a ton is a relatively expensive method of supplying oxygen demand. If sodium nitrate reacting with water is able to supply 4 atoms of oxygen instead of 2½ or 3, the effect in cost would be significant.

Since wastes treated with nitrates may be used to irrigate lands which are subsequently to be cultivated, the difference in fertilizer value will be a considerable item, depending on whether the added nitrate nitrogen is lost as N_2 or is retained in solution as NH_4HCO_3.

The ammonium bicarbonate, if formed, would raise the pH and suppress the evolution of H_2S, thus perhaps accounting in part for the very excellent results in odor elimination reported for the use of sodium nitrate.

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Stream Pollution

FACTORS INFLUENCING SELF-PURIFICATION AND THEIR RELATION TO POLLUTION ABATEMENT *

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Fundamental to any stream pollution abatement program is the evaluation of the factors influencing self-purification. Streams cannot be generalized. Each has its particular characteristics of drainage area, topography, climatic setting and pattern of runoff, which in turn, are reflected in specific natural self-purification capacities. These capacities primarily determine the extent and degree of pollution abatement necessary to meet the requirements for intended water uses. Some rivers can safely handle large quantities of pollution, while others degenerate from relatively small quantities of waste. A sound economical solution for pollution abatement rests, therefore, fundamentally on evaluation of self-purification capacity for each particular stream.

Natural Purification Analogous to Finance

In discussing the factors influencing self-purification, it may be helpful first to sketch the nature of the phenomenon in familiar terms of financial simile, so aptly stated some years ago by Prof. Earle B. Phelps. The best single measure of municipal sewage and industrial waste pollution is the quantity of oxygen required to stabilize it by natural biological processes of decay, or biochemical oxygen demand. Where pollution is discharged into a stream, the oxygen requirements to satisfy this demand are obtained from the oxygen dissolved in the river water. If the demand for oxygen is excessive in relation to that available, the D.O. is exhausted and the stream goes into complete bankruptcy.

Thus, the B.O.D. of pollution may be regarded as liabilities—outstanding debts—and the D.O. of the river water as assets. Stream solvency depends, therefore, on the relation of liabilities to assets, where oxygen instead of dollars becomes the medium of exchange.

In order to evaluate the solvency or condition of a stream it is essential to know the nature of this "business," particularly the rates of transactions, how fast debts are amortized, and the volume of income from the asset sources.

The amortization schedule of the biochemical oxygen debt is peculiar, but very sound. Mother Nature is an exacting banker, insisting upon a short amortization period with no postponement of the evil day by putting off payments until the end. She will not even tolerate equal daily installments; rather, she insists upon heavily unbalancing the schedule, with the larger amounts coming due in the early periods. And then, to make doubly certain of payment, when temperature rises and business accelerates, she shortens the amortization period. And if any one should be so foolish as to go into debt beyond capacity to pay, she sends in the wrecking crew, the anaer-

* Presented at 19th Annual Meeting, New York State Sewage Works Association; New York City; January 17, 1947.

obes, who literally tear block from block, extracting her payments and reducing the stream to a foul, putrescible ruin.

Similarly, there are characteristics peculiar to the income or asset side of this business. There are but two dependable sources of income, oxygen contributed from increments of stream runoff along the course of the river and oxygen absorbed by reaeration from the atmosphere.

Again, conservative Mother Nature, in the larger pattern of her ultimate economy, places a ceiling on the income producing assets of the business, fixed by the oxygen saturation level of water exposed to the atmosphere. Since the saturation level is dependent upon temperature, lowered as temperature increases, the income capacity is least during warm weather. The condition which produces the greatest strain on the business is, therefore, a period of high temperature and low runoff.

Liability Factors

With this thumb-nail sketch of the whole business, let us view in more detail some of the specific factors involved, considering first the liability side. (The general description of the business is applicable to both fresh water and tidal streams, but discussion will be limited to fresh water rivers, as consideration of tidal factors would lengthen this paper excessively.)

Effect of Temperature

The satisfaction of the biochemical oxygen demand is a time-temperature function. Figure 1 is a graphical representation of the amortization schedule for *normal* demand. The scale to the left represents the per cent of the debt remaining or left unpaid at the end of any interval, while in reverse, on the right, the scale represents the per cent of the debt paid up to any interval. The abscissa scale is the amortization period in days. It will be seen that as the temperature increases, slopes of the curves increase and the period to amortize the debt decreases. At normal summer temperatures (20° C.), practically the entire oxygen demand (99 per cent) is paid in 20 days; while at cool temperatures of 10° C., the amortization period is extended to about 32 days; whereas at hot weather

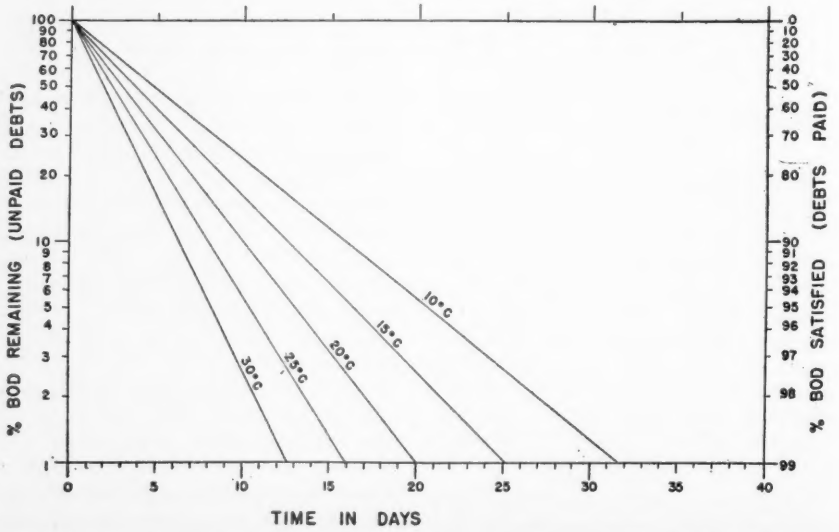

FIGURE 1.—Amortization of normal demand at temperatures of 10° C. to 30° C.

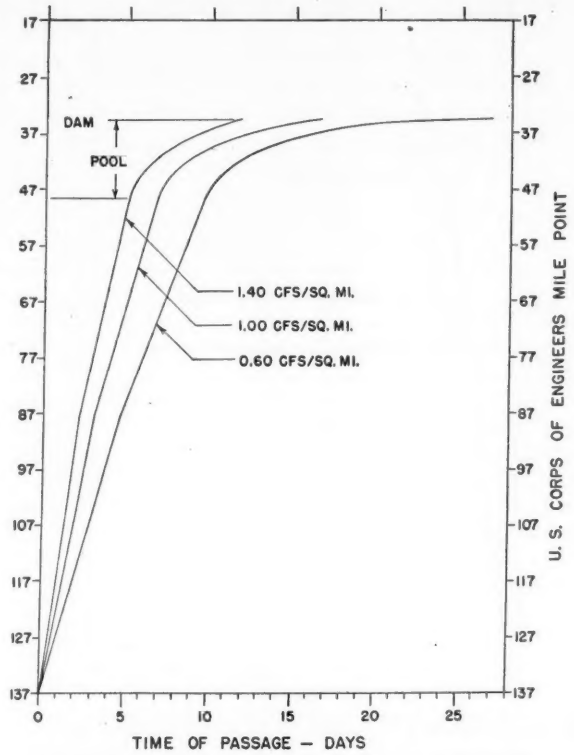

FIGURE 2.—Influence of runoff on time of passage.

temperature (30° C.) debts must be paid in about 13 days.

The unbalanced nature of the amortization schedule is also apparent. For example, in the first day, at 20° C., about 20 per cent of the debt would have to be paid, while on the twentieth day only 0.25 per cent is paid. Likewise, in the first three days one-half of the debt would be amortized, with the second half of the debt spread over the remaining 17 days. Furthermore, as temperature increases and the amortization period is shortened, the unbalancing with respect to early payment of debt is accentuated.

Time of Flow

Translating this to pollution moving down the course of a stream, the amount of debt required to be paid by the river becomes a function of the temperature of the river water and the time of passage of the pollution down the stream. The time of passage of pollution moving down the course of a river is essentially dependent upon volumetric displacement of river channel water by runoff. Time of passage, therefore, is a function of occupied channel volume and runoff. Channel volume varies along the course of the stream, depending upon topography, and is most accurately obtained from cross-section soundings at frequent intervals. Volume must be referred to runoff, however, as a change in runoff induces a change in river stage, and hence, affects occupied volume. The changes in occupied volume and runoff are so balanced that a decrease in runoff produces an increase in time

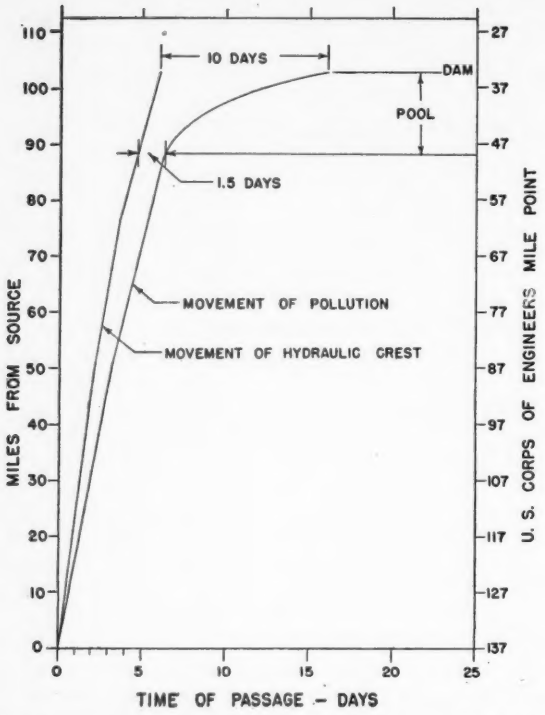

FIGURE 3.—Comparison of movement of pollution and of hydraulic crest.

of passage. The dominant influence of runoff in determining time of passage is indicated in Figure 2.

Alteration in the natural river channel such as the introduction of a dam and large storage pool in the zone of pollution will increase and alter the time of passage pattern, and hence, increase and shift the debt amortization burden along the course of the river. It is understood that while extra detention time does increase the proportion of the debt paid, a pool also provides an increased volume for reaeration. Whether such a pool is, in the end, detrimental or beneficial to the river depends upon which effect is greater, additional deoxygenation or additional reoxygenation.

On the other hand, artificial storage above the zone of pollution, operated to augment low runoff, may materially increase the critical dry weather flow and thereby shorten the natural time of pasage, and thus reduce the payments required for debt amortization. Also, the extra increment of runoff would add to the income. Such storage is beneficial. Operation of an upland storage for diversion of waters during critical dry weather periods will, however, have the opposite effect and will be detrimental.

In considering time of passage, it is essential to differentiate between two concepts, the movement of the hydraulic crest reflecting the time at which changes in runoff would be noted at locations down the river, and the movement of pollution along the stream. A unique opportunity was afforded for comparison of these two concepts under the same runoff conditions, as shown in Figure 3.

Data reported by operators at power plants established the time of passage

of the hydraulic crest, and the time of passage of pollution was obtained from volumetric displacement computations, checked by chemical tests on the movement of pollution. The hydraulic crest, more in the nature of translation of a surface wave, outstrips the movement of pollution contained in the body of the water, particularly where large volumetric displacements are involved through pools behind dams. This is strikingly apparent from Figure 3, where it will be noted that the hydraulic crest reaches the pool about 1.5 days sooner than the time of pollution, while through the pool, the hydraulic crest reaches the dam 10 days ahead of the pollution. These two times of passage have an important bearing on stream evaluation work, the hydraulic crest in relation to interpretation of sampling along the river course, which will be discussed later; and of course, the movement of the pollution is the real time factor employed in the amortization schedule of the biochemical oxygen debt.

Pollution Load

In addition to time and temperature, a vital factor to be considered is the debt itself, the location and magnitude of the pollution loads, and where industrial wastes are involved, the character of the debt. Thus far we have considered a *normal* debt, that is, oxygen demand associated with the heterogeneous mixture of organic matter contained in average municipal sewage. In some instances the normal demand is modified by large concentrations of specific industrial wastes. Two such

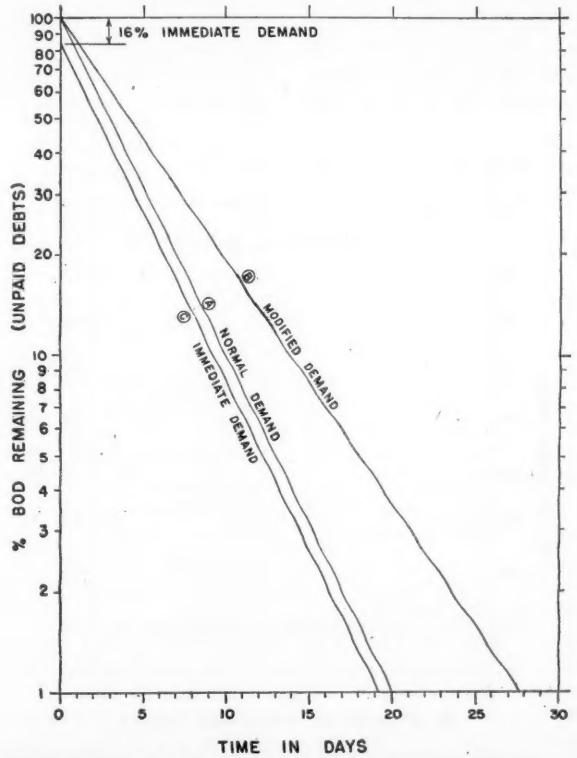

FIGURE 4.—Deviations from normal demand at 20° C.

modifications most common are the changes in the slope of the debt amortization curve and the immediate demand. These factors can be investigated by developing B.O.D. curves for the particular wastes involved.

Figure 4 is illustrative of the deviation from the normal amortization curve induced by these two factors. Curve A shows the normal demand at 20° C.; curve B shows the modified demand for a sulfite waste (1), which is of the same form but of less steep slope, allowing 27.7 days for amortization of 99 per cent of the debt, as compared to 20 days for the normal. Curve C indicates the effect of an immediate demand on the amortization schedule. Immediately upon discharge of waste into the stream, 16 per cent of the debt was paid, following which, however, payments are along a normal slope. This immediate demand does not make much difference in the total amount of debt paid over a 20-day amortization period, but it does seriously unbalance the schedule by a heavy demand in the first days, which may be sufficient to deplete the oxygen of the river immediately below the points of discharge.

Effects of Sludge Deposits

A third major factor which can, under certain conditions, distort the normal debt amortization schedule is sludge deposits. While the potentiality for sludge deposits depends upon the proportion of the B.O.D. load in suspended form, the actual role played by deposits is determined by hydrologic characteristics of the particular river. For deposits to occur, river velocity and turbulence must be reduced to where subsidence is possible. Critical velocity of runoff may result in a slight deposit spread over the entire course of the stream, the end effect of which would influence the normal amortization but slightly. In other instances, runoff and velocity conditions may result in heavy localized deposits within

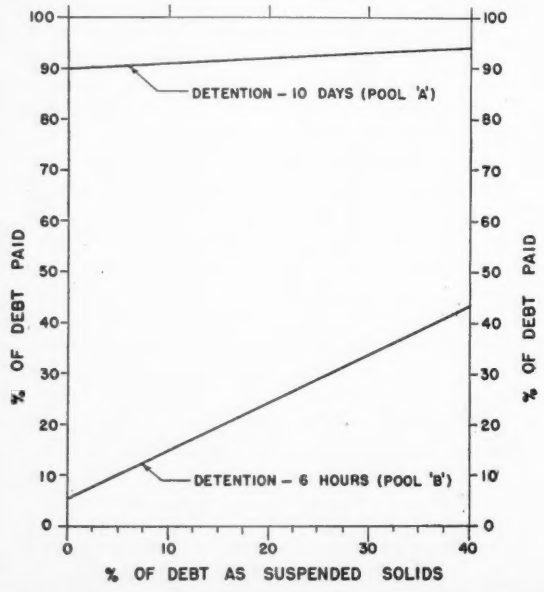

FIGURE 5.—Influence of sludge deposits on per cent of demand satisfied in pools of short and long detention.

a short distance below sewer outlets, or in pools behind dams. Whether such sludge deposits will appreciably influence the debt amortized depends to a large extent upon the time of passage through the zone of deposit, as illustrated in Figure 5.

Curve A is for a pool with a long time of passage, 10 days, while curve B is for a pool with a short time of passage, 6 hours, with velocities in both which permit subsidence. The debt amortized in the pool is shown on the ordinate scale as a percentage of the total B.O.D. load entering, and the abscissa scale indicates the proportion of the total B.O.D. debt in suspended form. If there were no suspended solids and the entire pollution load to the pool remained in the moving overlying water without deposit of sludge, Pool A would be required to amortize 90 per cent of the debt, while Pool B, with only 6 hours time of passage, would be required to satisfy but 5.5 per cent. On the other hand, if 40 per cent of the total pollution load consisted of suspended solids, all of which are deposited and completely satisfied in the pools, then the combined effect of sludge deposits and moving pollution in Pool A would increase the debt amortized by only 4 per cent, but for Pool B the debt amortized increases from 5.5 per cent to about 43 per cent. The net effect of sludge in the pool with long detention period would be negligible, while the increase in demand from sludge deposit may bankrupt the pool with the short detention. Of course, any extra payments made in the pool areas by virtue of sludge deposits lessen by those amounts the amortization burden on the downstream reaches of the river.

The example of Figure 5 is representative of warm weather active conditions where the daily payments required of accumulated sludge are approximately equivalent to the amount of the debt added each day as new deposit. During periods of falling temperature the daily demand from the accumulated deposits will decline and may be substantially less than that equivalent to each day's deposit. On the other hand, a hydrologic situation may occur under some conditions such that in the transition from spring to summer, with a sudden rise in temperature, unamortized sludge accumulated during the cold weather would exert a sudden heavy demand, substantially in excess of that which could be expected from deposits of current discharges of pollution, and thereby bankrupt a stream. This seldom occurs except in unusual situations, as spring floods usually scour out winter accumulations before warm weather sets in. While the fraction of debt amortization associated with sludge deposits may be highly variable and complex, whether such deposits play the dominating role in determining stream solvency will depend primarily on the time of passage through the zone of deposit.

There are two schools of thought with respect to evaluating the various factors influencing the oxygen demand amortization; one group lumps all factors into a single deoxygenation constant; the other group, to which the writer subscribes, evaluates each factor separately and combines the end results in terms of debt paid. So many factors are involved, which vary radically along the course of the river and change with runoff, that considering each separately, although entailing a great volume of computations, permits a much more refined evaluation of the pollution liabilities.

Asset Factors

Let us now turn briefly to the consideration of some of the factors influencing the asset or income side of the ledger. For convenience, these factors have been classified into five groups: D.O. from increments of runoff; reaeration; algae; stored D.O.;

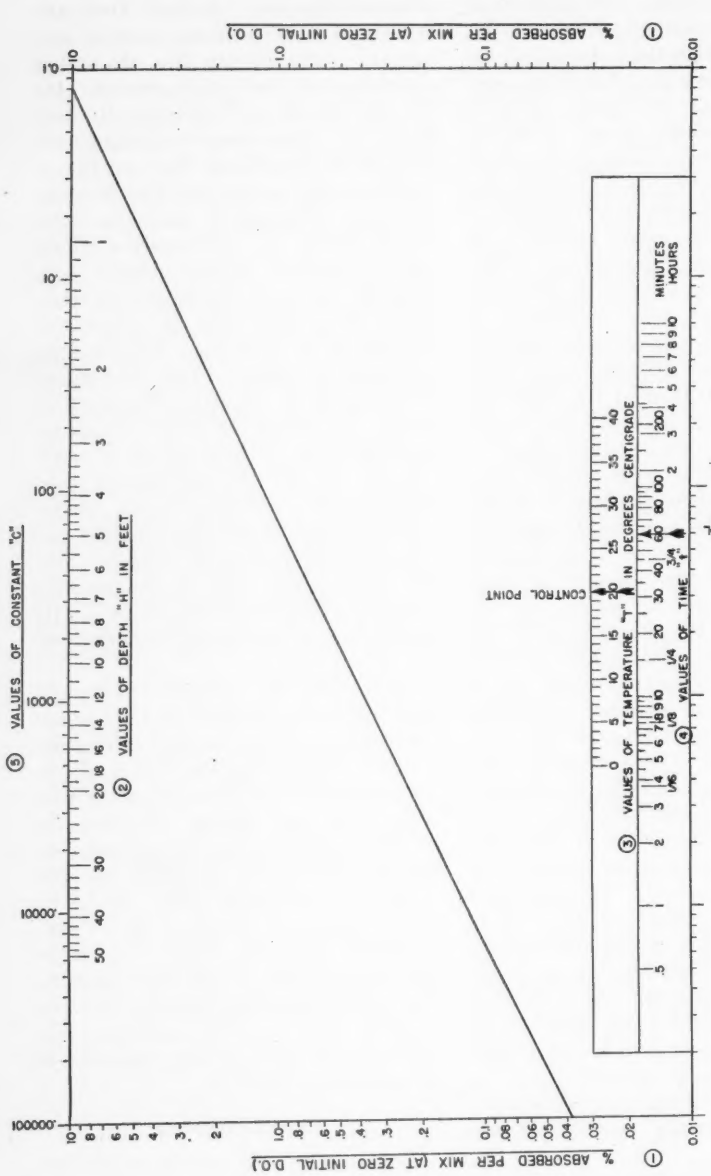
① % ABSORBED PER MIX (AT ZERO INITIAL D.O.)
① % ABSORBED PER MIX (AT ZERO INITIAL D.O.)
⑤ VALUES OF CONSTANT "C"
② VALUES OF DEPTH "H" IN FEET
③ VALUES OF TEMPERATURE "T" IN DEGREES CENTIGRADE
④ VALUES OF TIME
MINUTES
HOURS
CONTROL POINT
CONTROL POINT

FIGURE 6.—Standard Reoxygenation Curve. Example of use of chart: Given: Depth 10 ft.; Temp. 25° C.; mix interval 30 min.; initial D.O. content at 75 per cent saturation. Solution: Slide control of scale (3) to coincide with 10 ft. on scale (2); opposite 25° C. on scale (3) read on scale (5) "C" 0.00024; slide control of scale (4) to 0.00024 on scale (5); opposite 30 minutes on scale (4) read on scale (5) "C" 0.000122; drop vertically from "C" 0.000122 to the Standard Reoxygenation Curve and opposite this intersection read on scale (1) 0.41 per cent saturation; convert to per cent absorbed per day at initial D.O. content of 75 per cent, $0.41 \times (1.00 - 0.75) \times 1440/30 = 4.92$ per cent.

and negative D.O., the first two being the most important.

Dilution

The quantity of oxygen contributed from increments of runoff is primarily dependent on the rate of runoff and is subject to contraction or expansion with drought or abundant water yield. It is also dependent upon the quality of the tributary waters. If tributaries themselves are polluted, the D. O. contributed to the main stream may be negligible, or what should be a source of income may carry a liability. The income from good quality tributaries, moreover, is limited to the oxygen saturation concentration of water exposed to the atmosphere, which decreases as temperature increases. D.O. content seldom reaches full saturation even on virgin watersheds, and it is unsafe to rely on more than 85 per cent of saturation.

Reaeration

The rate of oxygen income from atmospheric reaeration is a highly variable and complex asset. The rate of income is dependent upon the amount of cash on hand; if the bank is full (water saturated) there is no income; if the oxygen is completely exhausted, the rate of income from reaeration reaches its maximum; and between these extremes, rate is directly proportional to oxygen deficit below saturation. While oxygen deficit is the throttle which regulates the rate of income, the actual amount received from reaeration depends upon the physical and hydrologic characteristics of each particular stretch of the river course. These characteristics can be grouped under four factors for any river stretch as mean water temperature, mean depth, occupied channel volume and stream turnover. Each of these factors is readily measurable except turnover, which is a function of stream velocity and turbulence. Prof. Phelps (2) has related these complicating factors in the form of an equation which permits a determination of reaeration income from any stream condition. Figure 6 * is a graphical representation of Phelps' basic reaeration equation arranged in a manner to facilitate rapid solution.

Algae

The three remaining factors influencing income are undependable assets and of relatively less importance, but may under certain conditions be the explanation of peculiar business activity. Algae are a source of pure oxygen, and when present in large numbers, may add substantially to temporary income, but the income is available only during daylight hours. Moreover, when dependable assets are most needed, such as during hot, dry weather, large masses of algae may die and instead of being an asset, their decomposition may actually add to the liability load during the critical period. Figure 7 (3) illustrates the variation in D.O. caused by algae over a 24-hour period.

Nitrate Oxygen

Stored D.O. in the form of nitrates is in the nature of reserve assets. This oxygen is available as a last resource to prevent complete bankruptcy when D.O. is exhausted. It is not good business practice to draw on reserve assets for current operations. Much better to consider these reserves as a factor of safety against complete disaster and run the business on current income in the form of dissolved oxygen, with sufficient cash on hand margin to meet reasonable variations in day to day obligations.

Negative D.O.

Negative D.O. is operation in the red. It means more obligations on hand

* This graph is a refinement of that published in *Transactions*, ASCE, Vol. 104 (1939), p. 560, the series involved in the basic equation having been expanded to approximately five hundred terms.

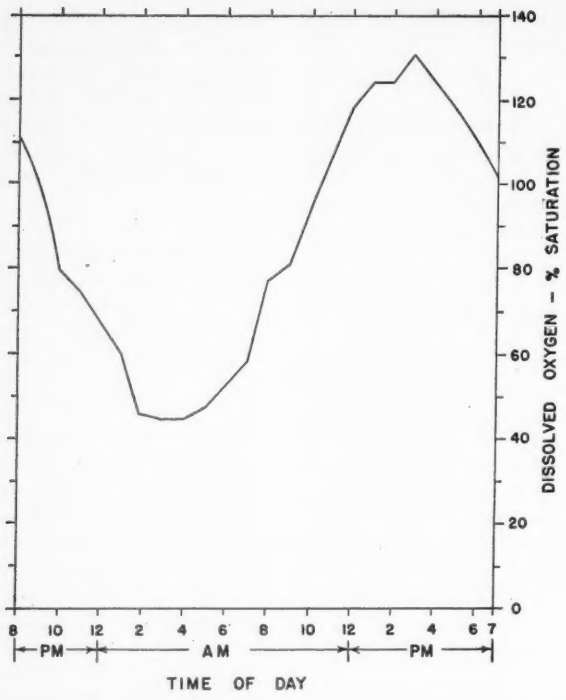

FIGURE 7.—Influence of algae on dissolved oxygen.

than cash and reserves available to pay. The result is H_2S, which if it remains dissolved in the moving river, may place an extra burden on resources downstream. On the other hand, if H_2S is lost to the atmosphere where the debt is paid by oxygen of the air rather than from the river water, such a loss of negative D.O. might be considered as bankruptcy proceedings, where at least the red is washed from the books and the river starts again from scratch.

As with the liability side of the business, the writer prefers to evaluate separately each of the factors influencing income, rather than to lump all of them into a single reoxygenation constant. Knowing the outgo and the income, the solvency of the business can readily be determined simply by striking a cash balance at a number of locations along the course of the stream. The result is a D.O. profile which defines the condition of the river.

Practical Application

The factors influencing self-purification are of more than academic or scientific curiosity; rather, we are interested in their practical engineering application to the design and evaluation of pollution abatement projects. The first step in practical application is the collection of the specific data for the particular stream involved. Such a sanitary survey should include three major groups of data, hydrologic, pollution load, and river sampling.

Data Required

The hydrologic data provide, in addition to runoff records, the equally essential but frequently neglected river cross-sections, from which accu-

pied channel volume, mean depth and time of passage can be determined. It implies also a detailed analysis of the characteristics of runoff, the variations in yield along the course of the river, the nature of the daily hydrograph (whether steady, fluctuating or punctuated with flash peaks), and most important, the probability of drought flows. The engineering profession is indebted to Prof. E. J. Gumbel (4) (5), for a fundamental statistical basis for analyzing the distribution of extreme values applicable to droughts. Time does not permit an explanation of his method, but we have applied it with remarkable success to the study of droughts on a number of rivers.

Figure 8 represents a distribution of minimum daily average and minimum monthly average droughts for a stream with a 46-year runoff record. From such a distribution one can readily obtain the drought severity of any frequency of occurrence. For example, the drought to be expected once in 10 years, as a monthly average value, would be 540 c.f.s., and as daily average value, 420 c.f.s. A comparison of the monthly average and the daily average curves indicates the importance of the runoff interval employed. As the interval over which runoff is averaged decreases, the drought flow increases in severity. The ideal interval to employ is that equivalent to the time of passage of pollution down the reaches of the river under consideration.

The second group of data to be collected consists of the location and size of the pollution loads, which involve the determination of volume and B.O.D.'s of municipal sewage and industrial wastes, including investigation where necessary for immediate demand and abnormal or subnormal B.O.D. rate curves.

The third group, river sampling, involves selection of sampling stations,

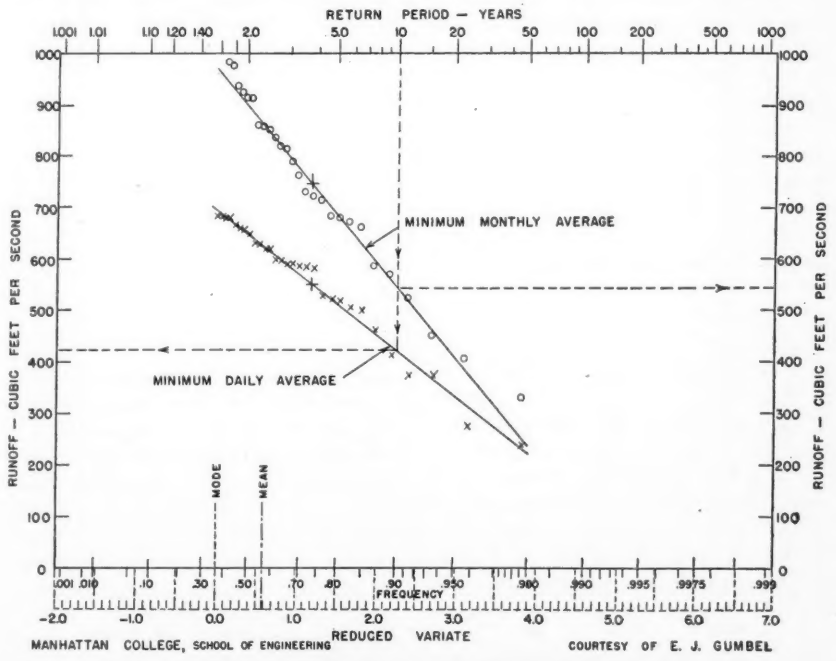
RETURN PERIOD — YEARS
1.001 1.01 1.10 1.20 1.40 2.0 5.0 10 20 50 100 200 500 1000
RUNOFF — CUBIC FEET PER SECOND
MINIMUM MONTHLY AVERAGE
MINIMUM DAILY AVERAGE
MODE
MEAN
.001 .010 .10 .30 .50 .70 .80 .90 .950 .980 .990 .995 .9975 .999
FREQUENCY
-2.0 -1.0 0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0
REDUCED VARIATE
MANHATTAN COLLEGE, SCHOOL OF ENGINEERING
COURTESY OF E. J. GUMBEL

FIGURE 8.—Distribution of droughts (46-year record).

relation of sampling period to runoff hydrograph, extent and frequency of sampling, and types of analyses. Somehow, observed results of river sampling have come to be revered and accepted as absolute reflection of stream conditions, regardless of how taken. River samples can be very misleading, presenting a false picture of the nature of self-purification, particularly when they are expressed as averages over a fluctuating runoff period. To be representative of stream conditions for any particular runoff level, sampling must be correlated with a period of *steady* runoff, with the first sampling preceded by a period of steady flow equal to the time of passage of pollution.

For example, samples taken after a peak flow, though taken during a steady flow period, are radically distorted by the preceding peak discharge, the hydraulic crest of which has passed, but the pollutional effects of which have not passed down the river until the steady flow prevails for a period at least equal to the time of passage of the pollution. During periods of fluctuating runoff, samples along the course of the stream really represent a combination of several profiles at different runoff yield levels, the mean of which does not necessarily represent a profile for a steady runoff equivalent to the mean flow during a fluctuating discharge. The apparent wide variation in deoxygenation and reaeration constants reported in the literature in many instances may be attributed to averaging observed sampling data without regard to the daily runoff hydrograph.

Frequent sampling, at least daily, over a short period of two to three weeks, correlated to steady runoff and with time of passage, is far more valuable than infrequent, random sampling

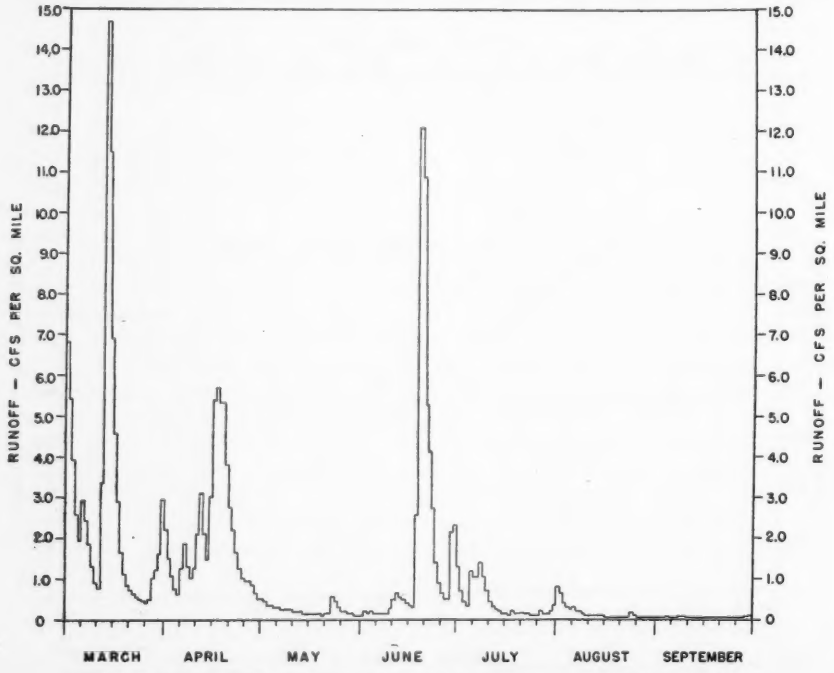

FIGURE 9.—Daily hydrograph of Scioto River at Columbus (1939). Drainage area 1,624 sq. mi.

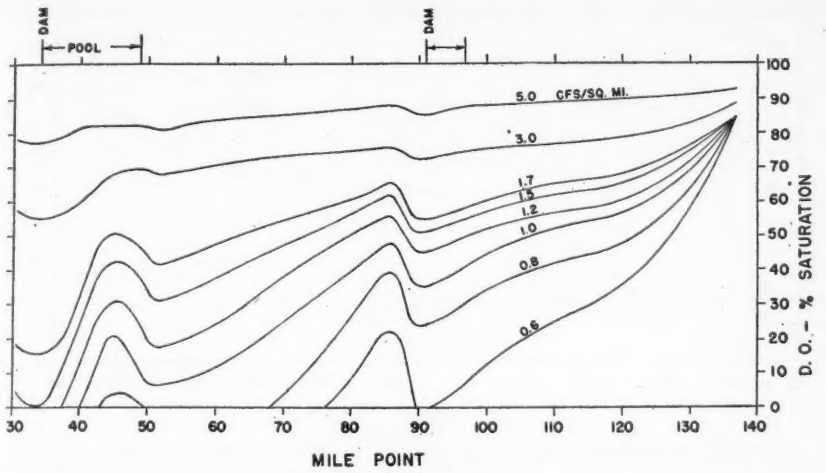

FIGURE 10.—Influence of runoff on dissolved oxygen profile (0.6 to 5.0 c.f.s. per sq. mi.).

spread over several months of widely fluctuating runoff. Referring to the hydrograph, Figure 9, a poor time to take samples would be during the period of fluctuating runoff punctuated with peak discharges noted in the spring and in June and early July. Concentrated sampling during the steady flow of September would be ideal.

All that is required is one good profile at a steady runoff level. Profiles at other runoff levels can be computed in less time, at less cost and with equal or greater accuracy than river sampling.

Interpretation and Use of Data

Too frequently, stream pollution evaluation ends with the sanitary survey, when actually it is just the beginning of practical application to pollution abatement. With the data gathered, the next operation is a check computation of D.O. profile, as verification of proper application of the numerous factors at play influencing liabilities and assets. If computed and observed river sample profiles are in reasonably close agreement, it is safe to proceed with computations for other runoff conditions and for various reductions in pollution load proposed.

Figure 10 represents such computations on one of the streams we are investigating, which illustrates the influence of different levels of steady runoff on the D.O. profile. From such computed curves it is possible to predict for this river and this pollution load the D.O. profile at any runoff.

Figure 11 illustrates the effect on the D.O. profile of proposed reductions in pollution load, at a runoff of average drought conditions. On each curve is indicated the residual pollution load expressed as a percentage of the original untreated load. Similarly, on Figure 12 are the profiles at a drought of severity to be expected once in 5 years.

To proceed with the design of a remedial program without evaluation of the factors influencing self-purification is unsound and uneconomical, and the effectiveness of treatment works, perfect in mechanical detail, may be very disillusioning to the tax-payer and to those who wish to make use of the river.

In addition to determining where, when and how much to treat, such

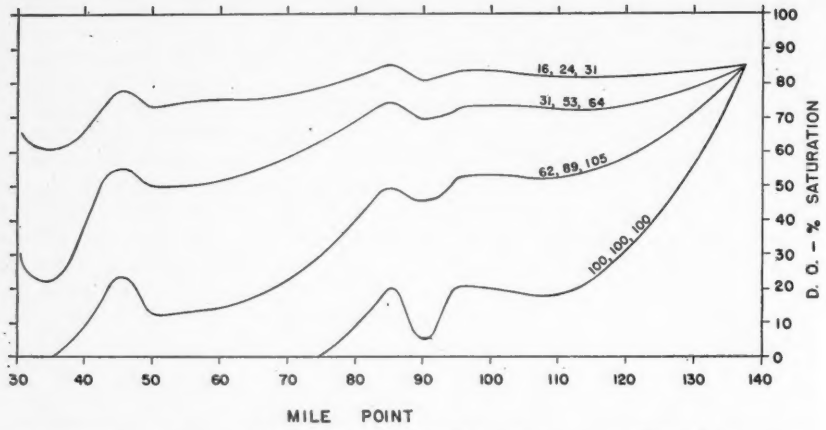

FIGURE 11.—Influence of pollution load on dissolved oxygen profile under average summer drought conditions.

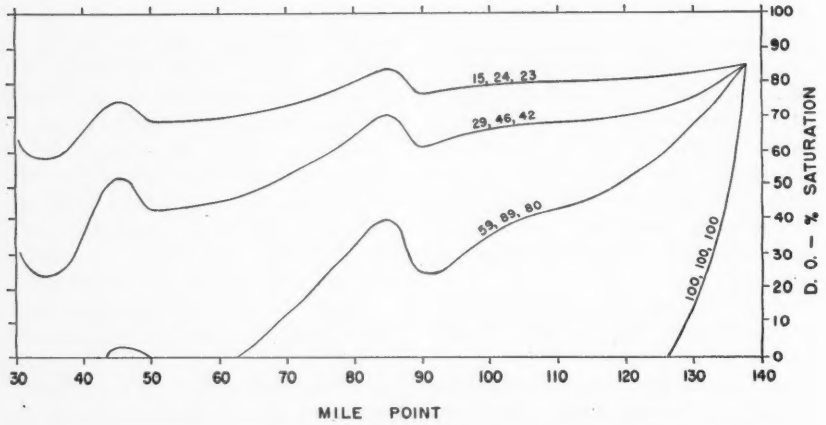

FIGURE 12.—Influence of pollution load on dissolved oxygen profile under 5-year drought conditions.

evaluations indicate the type of treatment and the particular fraction of the pollution load best to be removed. For example, if sludge deposits are responsible for a critical D.O. condition, sedimentation treatment may be adequate; on the other hand, if immediate demand induces a sharp drop in D.O. to critical levels, an entirely different type of treatment may be called for.

To illustrate, we have applied in Figure 13 these two characteristics of load to a river where the other self-purification factors were known, for a drought of severity to be expected once in 5 years. Based upon the assumption that the pollution load has a normal amortization schedule, but stream characteristics permit a sludge deposit in the zone below points of pollution, curve A indicates the effect of a 40 per cent reduction in the pollution load by sedimentation treatment. This treatment raises the D.O. to about 50 per cent of saturation at the low point of the sag at Mile Point 53, which

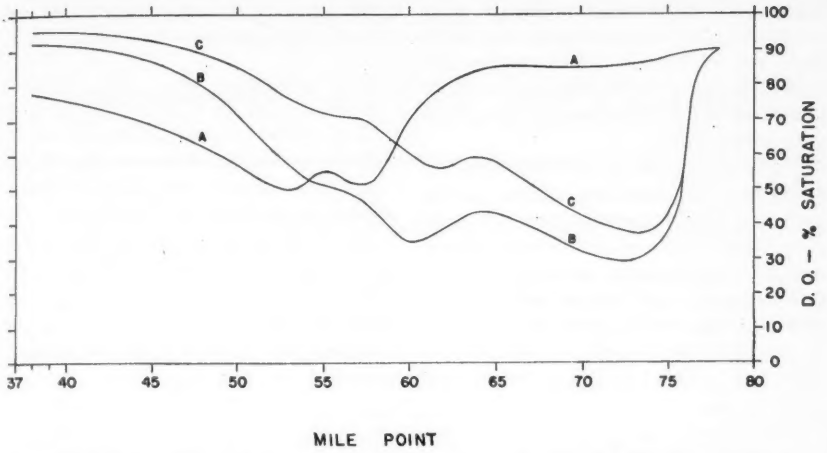

FIGURE 13.—Relation of characteristics of oxygen demand to treatment required.

would be adequate. On the other hand, assuming that the pollution contains in solution a small immediate demand equivalent to 16 per cent of the load, and that the remainder of the demand is normal, sedimentation treatment, while removing the suspended solids fraction of the load, would not be effective in removing immediate demand in dissolved form. In this case (curve B) the D.O. would drop to less than 30 per cent and the low point of the sag would be moved up the river 20 miles. Resorting to chemical coagulation to reduce the load by 65 per cent, the unremoved 16 per cent immediate demand would still hold the D.O. down to about 37 per cent (curve C). For this particular stream it is obvious that if dissolved immediate demand is the dominant factor the type of treatment should be aimed primarily at this fraction of the debt. Certainly the effect on the stream of sedimentation and coagulation would not only be disillusioning, but investment would have been made in the wrong type of treatment.

Pollution Control Policies

The control of stream pollution and the design of remedial programs hinge on two basic policies. First is determination of anticipated water uses and the quality tolerances required for such uses. Second is the relation of these intended uses to the probability of drought flows. Decision as to these two policies includes, in addition to technical determinations, consideration of practical economic factors.

Obviously, it is not economically feasible to provide treatment which insures the desired stream conditions during drought flows of such rarity of occurrence as once in 100 years. On the other hand, it would be an economic waste to provide such limited treatment that the stream would degenerate below desired utility levels every year or two. Between these extremes lies the practical solution.

Whether you will get for your money what you expect to get at any risk of drought severity depends upon the prior evaluation made of the factors influencing self-purification. The day of the old country doctor is past when "if this pill doesn't work, well, let's try another." Today we wish to know in advance of expenditure for construction what effect the treatment works will have upon the stream, and if it will be adequate for the water uses

intended. Likewise, the day is past when stream standards and classifications are arbitrarily fixed and then applied wholesale to all streams, without regard to their individual self-purification capacities.

As is evidenced by interest and activity in such stream evaluations on the part of industrial groups, federal agencies, departments of health and stream control commissions, sanitary science has matured, and has advanced to a position comparable to other branches of engineering in ability to predict what you will get for your money and guarantee reasonably that you will get what you expect.

Acknowledgment

The writer wishes gratefully to acknowledge the assistance of Mr. Ernest Tsivoglou, present recipient of the research fellowship at Manhattan College School of Engineering granted by the National Council for Stream Improvement of the Pulp, Paper and Paperboard Industries, Inc., in the computation of much of the background material for this paper.

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THE OPERATOR'S CORNER

TRY THAT NEW INDUSTRY ON FOR SIZE

A recent inquiry from a well-known Ohio plant superintendent sought information concerning the nature and volume of liquid wastes expectancy from two new industrial plants which are soon to begin operations in his bustling city. One of these plants will refine beet sugar (concerning which we could recommend no better general reference than Chapter IV of the book "Industrial Waste Treatment Practice" by E. F. Eldridge), and the other will prepare and pack stuffed olives (upon which we could give no references and suggested direct contact with plant officials).

The point meant to be emphasized here is that the alert Ohioan is not waiting for these plants to start production before he concerns himself about the effects of their wastes on the city sewage treatment plant. He is arming himself with all the advance information he can gather, so that he will be prepared for what might happen when the industries commence operations.

Even so, it is a bit late for the sewage works superintendent to be getting into this picture—he should have been consulted before the industrial officials decided finally upon the location of the new plants in the city. This is the case, however, more times than not. The local chamber of commerce, in its zeal to encourage industrial development, will overlook or minimize the problem of waste disposal as a minor detail, often to find later that a disservice has been done both the industry and the municipality. There are many cases of record to exemplify such mistakes.

Large industrial concerns, experienced in the establishment and operation of small branch plants and factories, are most likely to include wastes disposal among the local factors that govern such branch locations. Smaller concerns that may be expanding for the first time and local citizens developing a new enterprise, however, may not appreciate that wastes disposal may be equal or greater in importance to such factors as labor, raw materials, transportation, water supply, fuel, market, etc., in determining the suitability of an industrial site.

It is the municipalities of small and moderate size that must be most wary of over-reaching themselves in this respect. The average businessman or city official cannot be expected to know what overloads or effects the wastes from the proposed cheese factory, cannery, textile mill or brewery will have on the sewage treatment plant. And that is where the sewage works superintendent takes the stage—in the capacity of specialist advisor.

The superintendent cannot be dilatory or bashful, however, and must take the lead in educating his council and the local chamber of commerce secretary concerning the pitfalls of the open-arm approach to all industries. He should also familiarize himself through the literature with the nature of industrial waste problems in general, so that he will know when to flash the green or the red light. When he is doubtful he should not hesitate to recommend that the advice of a qualified consultant be secured.

W. H. W.

1946 OPERATORS' FORUM *

H. S. NICKLIN, *Chairman*

President (1946), The Canadian Institute on Sewage and Sanitation

ACTIVATED SLUDGE PROBLEMS

Bulking and Rising Sludge

L. F. Roberton, Superintendent of Sewage Treatment, London, Ont.—Of the three sewage treatment plants serving the city of London, the largest is the West Side plant, which receives a maximum flow of 9 m.g.d. This flow includes domestic sewage from 65,000 persons with trade wastes from a brewery, tannery, hosiery mills and creameries. The operation of this plant is continuously complicated by the presence of rising and floating sludge in the final tanks, which condition is believed to be caused by the heavy overload and the brewery wastes in particular.

The aeration tanks are built as three individual units, and we can control the flow to them. We have had success in controlling the sludge condition by diverting part of the flow from one unit to another for reaeration. We also chlorinate continuously at the aeration tanks, although we have had difficulty in procuring chlorine this year on account of a strike.

Further, we apply ferric chloride to the sewage entering the settling tanks and add lime at the reaeration tanks.

D. E. Bloodgood, Assoc. Professor, Purdue University, Lafayette, Ind.—What is the purpose of the lime application?

Mr. Roberton—The main sewer to the West Side plant operates as an inverted siphon and the sewage upon arrival at the plant is quite septic in the summer. The lime aids in conditioning the sludge during reaeration. As a rule we do not use much lime if we can get chlorine for application at the aeration tanks. We could not obtain enough chlorine this year.

L. S. Kraus, Chemist, Peoria (Ill.) Sanitary District—Is the troublesome condition you describe due to denitrification of the sludge, causing a floating layer on the tank surface, or is it due to the inability of the sludge to settle?

Mr. Roberton—We get both conditions.

As an additional cause of the floating sludge at the final tanks we have animal hair from the tannery, some of which passes through the fine screens preceding the activated sludge units. We do not at present have primary settling tanks.

Mr. Bloodgood—I would like to ask Mr. Kraus to define bulking sludge.

Mr. Kraus—The ordinary conception of bulking is a condition under which a sludge of normal solids concentration will not settle out within the limits of the plant to handle activated sludge. That is, if the return sludge capacity in a plant is less than that required to remove the sludge from the final settling tanks, the activated sludge is in a bulking condition.

In the Peoria plant, the sludge is bulked when the sludge index is about 350. In other plants the condition might prevail at an index of 250 or at some other level.

E. J. M. Berg, Superintendent of Sewage Treatment, San Antonio, Texas—I am interested in this rising sludge condition, which according to my understanding, occurs when there is a fair amount of nitrate in the mixed liquor. When this nitrate decomposes, releasing gaseous nitrogen, the rising

* From transcript as reported during Twentieth Annual Meeting of the Federation of Sewage Works Associations; Toronto, Ont., Can.; October 7–9, 1946.

bubbles of gas tend to carry along part of the sludge.

At San Antonio we seem to have contradicting conditions in that the activated sludge is well-nitrified but does not settle well, as it apparently should. The index of this well-nitrified sludge is in the bulking range, and its poor settling is just as bad in its consequences as would be the rising tendency.

We have found that an overloaded condition—when air and return sludge capacities are inadequate to handle the sewage load—will give bulking sludge. We are never able to persuade the excess activated sludge to settle in the primary settling tanks. Hence, we have had to send it to the digesters, with the result that there has been a heavy load of digester supernatant.

We return—to the aeration tanks or primary tanks—from 60,000 to 100,000 g.p.d. of supernatant having a B.O.D. of 800 to 1,000 p.p.m. and suspended solids of 1,000 to 1,500 p.p.m. The return of as much as 100,000 gal. of this liquor to a daily flow of 25 m.g. will bulk the sludge.

Occasionally we receive a very heavy discharge of slaughterhouse wastes. This seems to bring on a case of bulking almost within the 20 or 30 minutes it takes to walk from one end of the plant to the other on a routine inspection.

To correct and be prepared for these conditions, I try to maintain the return sludge rate, in terms of dry solids, at 10 to 15 times the incoming solids load in the settled sewage. For instance, with an estimated 10,000 lb. per day of solids in the settled sewage I would try to return about 100,000 lb. of activated solids in the reaerated sludge. The conditions of the previous day serve as a guide in this procedure, which requires continual supervision and good judgment in estimating the load.

When the air capacity is adequate to keep the required amount of return solids in a good active state, I am able to cope with bulking sludge. My experience has been that there must be sufficient solids in the aeration system to counterbalance the load that is coming in, and that there must be sufficient aeration capacity to keep the sludge thoroughly aerated.

We have been trying chlorination of the return sludge for the past two months, using the formula suggested by Tapleshay for calculating the amount of chlorine on the basis of the sludge index and quantity of return sludge (see THIS JOURNAL, **17**, 6, 1210 November, 1945). This procedure, together with the return of sludge solids at 10 to 15 times the amount of solids in the settled sewage, has apparently improved the settling qualities of our sludge. I say "apparently" because about four weeks after we started chlorination we began to get a lot of rain, and you all know what benefits rain brings to an activated sludge plant.

I would like to learn whether return sludge chlorination only improves the settling or if it also improves B.O.D. removal. I have some doubts about that.

Frank Woodbury Jones, Chemist, Havens and Emerson, Cleveland, Ohio —I have a small activated sludge plant under my supervision which has a capacity of 1 m.g.d. The flow is entirely domestic and amounts to only about 0.5 m.g.d. in dry weather. The plant is not overloaded, we have plenty of air, and the effluent is ordinarily of excellent quality—under 10 p.p.m. both in B.O.D. and suspended solids. Things go along beautifully, and then almost overnight the sludge turns to "feathers." I mean, literally, "feathers"—they just come up in the final tank and go over.

I cannot subscribe wholly to the nitrate theory because when the plant was operating at its very best, I personally made a determination of nitrates and when I got the result I

thought, "Well, you better go back and see whether your solutions are in order and try it over again." So I did, and got the same results. Now, with an excellent, sparkling clear effluent, the nitrates were 38 p.p.m., which is no mean concentration of nitrates!

After we got rid of the "feathers" we went there one morning and the sludge blanket was within one foot of the top. It didn't go over. The sludge looked good and the effluent was excellent—we were getting good purification.

My theory is that these conditions occur after long periods of drought. I just wonder if the sludge does not develop certain toxins and the only way you can cure the situation is just to thin the stuff out and start over again.

W. D. Hatfield, Superintendent, Decatur (Ill.) Sanitary District—I have had that same condition a number of times. The sludge is eventually going to go bad. I just can't conceive of sludge staying in the tank away from the air that long.

I would be interested to know something about the loadings on the various plants that have been discussed. I have always conceived the loading on an activated sludge plant in terms of B.O.D. I compute the load as pounds of B.O.D. daily per 1,000 cu. ft. of aeration capacity. I was interested to note that Mr. Berg thinks in terms of suspended matter in the sewage.

I never thought of the suspended matter having a particular relation to B.O.D. because our industrial wastes are mostly soluble and the suspended matters are always very low—60 p.p.m. —but the B.O.D. may vary all over the map. We find that as long as our loading is within reason, there is no problem. As soon as our loading goes above 35 to 45 lb. of B.O.D. daily per 1,000 cu. ft. of aeration capacity, we are in for bulking. That may be an entirely different condition than other plants have, but if we can hold our loading below that maximum range we are not bothered.

I feel that there is a connection between bulking and the B.O.D. loading on a plant, and yet so few people report B.O.D. loadings. I have gone over any number of annual and monthly reports from various plants, and I find that those that never report trouble with bulking are all loaded down at about 18 or 20 lb. per 1,000 cu. ft. When you figure it out, they are not loaded high. I believe it is the B.O.D. loading that is mainly responsible for bulking of activated sludge, although there are probably a dozen other factors influencing the sludge quality.

J. K. Hoskins, Asst. Surgeon General, U.S.P.H.S., Washington, D. C. —I wonder if any of the operators who have been troubled by these feather-like growths have examined them under the microscope and observed the biological growth when they have this condition, and observed the change when sludge in this condition is chlorinated?

Mr. Jones—We did not examine the feathery sludge under the microscope. We did, however, make an unsuccessful attempt to correct the condition by applying chlorine.

Air Requirements

Dr. F. W. Mohlman, Director of Laboratories, The Sanitary District of Chicago—This question of air requirements for activated sludge interests me because I think it brings up a good point with reference to our practice. It seems to me there should be more tendency to think in terms of the actual work that the air does rather than in terms of cubic feet per gallon; we are all familiar with the reporting of results in cubic feet of air per pound of B.O.D. removed.

There is a surprising variation in air requirements among different plants; they will range all the way from 1,500 cu. ft. per lb. B.O.D. removed to 500

cu. ft. and under. The value for the Chicago North Side plant is 500.

I have concluded that there is an irreducible minimum air requirement value for every plant that depends upon the strength and type of sewage treated. Where we have found this minimum to be about 500 cu. ft. per lb. of B.O.D. removed at the Chicago North Side plant, it has proved to be about 800 or 900 at the Southwest plant, where the sewage is quite different.

We pay careful attention to the dissolved oxygen in the mixed liquor during aeration, making about 200 checks a day on this condition. Air application is adjusted according to abrupt changes in D.O., particularly in regard to increased air when a sharp drop in D.O. takes place.

I was somewhat skeptical about this at first, but careful observation has indicated that if you permit the D.O. to drop 1 or 2 p.p.m. for any length of time there will be a change in the sludge and in plant efficiency. We consider aeration tank D.O. tests to be very important.

Some days we might observe, say, a drop in D.O. from 5 p.p.m. to 1 p.p.m. in a 4-hr. period. We immediately increase the air if we have more capacity, or decrease the flow if we do not have the air.

We also watch carefully our sludge index and rate of sludge return. By reviewing all of the operating data at our weekly staff meetings we are able to chart the course for the week ahead, hoping that there will not be an upsetting factor in the way of an unexpected load of packinghouse waste, oil or other industrial waste.

Mr. Berg—When our plant is running well, we require about 900 cu. ft. of air per lb. of *incoming* B.O.D. to secure an effluent containing 10 to 15 p.p.m. of B.O.D. and suspended solids. When the process is bordering on an upset, however, about 10 per cent more air is needed.

Notice that I am referring to air requirement on the basis of *incoming* B.O.D. and not on B.O.D. *removal.* I consider that it takes proportionately more air to treat a strong settled sewage than a weak one, so that the yardstick of cubic feet of air per pound of B.O.D. removed may not yield a true picture. Our expression of air requirement on the basis of the incoming B.O.D. load is probably also distorted unless comparisons are made only between settled sewages within the same range of strength. The operator who must treat a settled sewage containing 300 p.p.m. B.O.D. has a much more difficult problem than I, because our settled sewage never exceeds 150 p.p.m. and it takes much less air and effort to remove it.

The air blown through the sewage is not all the air that is doing the work. As the sewage turns over in the aeration tanks it absorbs quite an amount of oxygen that cannot readily be measured.

Mr. Bloodgood—I should like to supplement Dr. Mohlman's remarks about the interpretation of D.O. tests at the outlet of the aeration tanks. I am associated with a plant at which the superintendent informed me one day that the average D.O. at the end of the aerator for any one week was 2.5 p.p.m., and yet he was having difficulty. The detailed record showed that the weekly average was 2.5 p.p.m. all right, but one daily test was over 4 p.p.m. and another was practically zero. In that case the average did not tell the true story.

When the dissolved oxygen content of the aerated mixed liquor is near zero, even in one section of the aeration battery, it may result in bulking throughout the entire plant.

Paul A. Uhlmann, Consulting Engineer, Columbus, Ohio—I fully agree with Dr. Mohlman in the expression of air requirements in cubic feet per pound of B.O.D. removed. After all, the aeration tanks have a certain

amount of work to do on the loading they receive.

The strength of the settled sewage depends largely upon the characteristics of the settling facilities. We have under our supervision a plant that received a sewage averaging 600 p.p.m. B.O.D. over the year, due to the presence of canning, milk plant and stearic acid wastes. To remove this excessive B.O.D. we use chemical treatment ahead of the primary settling and, even so, the aeration process has to take a B.O.D. of 300 p.p.m. or more. The expression or air requirements in cubic feet per gallon of this sewage would not mean much.

In order to handle excessive loads it is necessary to consider aeration capacity against the incoming B.O.D. In evaluating plant performance, it is necessary, in our opinion, to refer to tank capacity per pound of B.O.D. removed.

Dr. Hatfield—I agree that, as a routine procedure, you can control the air application and loading by the dissolved oxygen test at the outlet end of the aeration tank. We have an industrial waste at Decatur, however, that may cause the B.O.D. of the settled sewage to rise from 150 p.p.m. during one hour to 450 p.p.m. two or three hours later. This does not happen too often, I am glad to say, but it may occur four or five times a month. We may also get smaller shock loads during the day that will not cause quite as much trouble.

At any rate, we moved our mixed liquor D.O. sampling point from the outlet to a location about a third the way down the length of the aeration tank. We find that this gives us a much quicker indication of the presence of an unusual load—we find out about it before it is too late to take remedial steps. We try to maintain at this one-third distance from 1 to 1.5 p.p.m. of dissolved oxygen. If the D.O. goes up to 2 or 2.5 p.p.m. we give the activated sludge plant a little more load.

The Decatur plant has trickling filters in addition to activated sludge units. It is possible to adjust the flow between the two secondary treatment processes and we try to run the activated sludge plant at its limit. The division of flow is controlled entirely by the mixed liquor D.O. test.

Dr. Mohlman—We make the D.O. tests at 5 points other than at the outlet ends of the aeration tanks, but we do not make the tests at the intermediate points so frequently. The outlet tests are used as our main control.

Dr. Hatfield—Our dissolved oxygen checks are made every 2 hours except when a shock load is found to be coming in. Then the frequency is increased to once or more an hour.

Trickling Filter Problems

Advantages of Trickling Filters

R. V. Anderson, Consulting Engineer, Toronto, Ont.—I suggest four reasons why the trickling filter might be selected in preference to other types of secondary treatment:

First is the flexibility possible in securing the degree of treatment desired. The first step in designing a plant is to determine the effluent B.O.D. that will be acceptable; if 30 p.p.m. is good enough there must be a special reason for selecting a process yielding an effluent containing 10 p.p.m. B.O.D. Trickling filters can be designed so as to produce almost exactly the quality of effluent desired.

Next, trickling filters are valued for their ability to withstand shock loads where the plant may be subjected to sudden loads imposed by industrial wastes. The preceding discussion has indicated that the activated sludge process is somewhat sensitive to such conditions. The trickling filter is also

readily adaptable to varying seasonal loads, as in resort communities.

Third, there is the simplicity of operation of trickling filters—an advantage of considerable value in the small community where a trained engineer or chemist cannot be employed. All sewage treatment plants have their operation problems, but these seem to be minimized in trickling filter plants.

Finally, there is the matter of costs. It has been our experience in these days of rising costs that trickling filters are often lower in first cost than is activated sludge treatment. (Note: It is pointed out later in this discussion that comparisons of construction costs between activated sludge treatment and conventional filters and between activated sludge and high rate filters may be quite different. Moreover, comparisons of operation costs of these types of secondary treatment will usually favor one or another depending upon pumping requirements, utilization of gas, etc.—*Ed.*)

L. R. Howson, Consulting Engineer, Chicago, Ill.—There is no such thing in my opinion as a type of plant that would fit all conditions. Each plant is tailor-made and the selection of units depends essentially on a study of the requirements and an analysis of the means of meeting those requirements in the most economical manner. There are, however, certain types of wastes for the treatment of which the trickling filter is usually indicated, and I agree with the previous speaker that such wastes are essentially those high in load, concentrated, and variable in character—variable not only through the season but variable in the hours of the day. There is one thing about a trickling filter: It never lets you down entirely; if it is properly designed any load will go through. To illustrate specifically, the trickling filter has demonstrated itself as being particularly applicable to wastes from packinghouses.

I know of one installation at a packinghouse which was handling waste with an annual average B.O.D. of 1,500 p.p.m. It is a three-stage filter plant, the initial stage being an aerator and water-wash roughing filter, which takes out about 65 per cent of the B.O.D., followed by two standard filters that can be operated either in parallel or in series. When operated in parallel they produce an effluent of about 30 to 35 p.p.m., and operated in series the final effluent averages about 13 p.p.m. This effluent goes into a dry stream.

I think roughing filters have an application to many domestic plants as illustrated right here in Canada at Moose Jaw. This plant has 13 units of an old English filter. It is a pioneer plant, grossly overloaded as the result of two large packing plants—one of them very large—and a cereal and milling plant. The raw B.O.D. of that waste averages over 2,000 p.p.m. while the present effluent runs 400 to 800 p.p.m. and is discharged to a dry stream.

In addition to the industrial wastes mentioned, one-third of the town is now provided with night-soil collection. The night-soil is brought in and dumped at the entrance of the plant during the night, so that one-third of the domestic population load is contributed without dilution. That makes a rather stiff requirement.

The solution of this situation is not too difficult. The first need is for a new primary settling tank, combined with storage, ahead of the existing primary treatment units. I think that one of the best possible investments that can be made in connection with the treatment of these heavy shock type wastes by trickling filters or anything else is in a storage tank equipped with water works type rate controls. During the day operations at the killing floors, both the concentration and volume of the packinghouse wastes are at their peaks. Storage and flow rate control facilities make it possible to

equalize rate and strength, and to utilize all or most of the full plant capacity during the night hours. Following the new settling and storage tanks will be installed a primary roughing filter to be loaded at about 8,000 lb. per acre-foot per day. The roughing filter effluent will pass through the present flocculator, clarifier, and the thirteen English filter beds, which are being split into eight intermediate units and five third-stage units, with a new intermediate clarifier between the last two stages. The effluent from the final filters will pass to the existing final clarifier and thence to the stream. It is believed that this treatment will produce an effluent satisfactory for discharge into a dry stream, that it will utilize everything that is now invested in the plant, and will require a comparatively nominal expenditure to accomplish the degree of treatment sought.

Trickling filters will take a substantial shock load and, when operated in multiple stages, will give any desired result.

Roy H. Ritter, Whitman, Requardt and Associates, Baltimore, Md.—Baltimore has the largest trickling filter installation in the world, built some 30 years ago. About ten years ago these filters became overloaded and it was recommended by some very prominent consultants that an activated sludge plant be built to supplement the filter treatment. A 40-m.g.d. plant was designed, but proved to be too expensive, so a plant of just half this capacity was constructed. Today the Bethlehem Steel Co. mill nearby takes the effluent from this plant for industrial water uses, giving additional treatment only by chlorination. When this plant is operated at above 12 m.g.d., however, the effluent is not suitable for use in the steel mill and they have to take the effluent from the old trickling filters.

Mr. Anderson mentioned that first costs of trickling filters were appreciably less than activated sludge treatment. I wonder if he might not have had high rate filters in mind when he made this statement. The standard rate trickling filter, I think, would be just as expensive in first cost as activated sludge.

Filter Fly Control

T. C. Schaetzle Senior Associate Engineer, Akron, Ohio—I had occasion to serve on the operation staff at the Baltimore plant to which one of the previous speakers referred, and I have been at the Akron plant for a number of years. Filter flies have been a real nuisance at both places. We have paid out considerable sums in Akron, as they did in Baltimore, for lawsuits resulting from the fly nuisance.

We are trying different methods of overcoming the problem and at Akron during this past summer I think we are the first ones at a large plant to try DDT for control. It is too early to report our results, but the treatment does show promise at dosages between 0.4 and 0.5 p.p.m. based on the total daily flow. How we should apply the DDT and over what period of time, we are not yet ready to state, but treatment at intervals of 1 to 12 hours seems to give the same results.

Our experiments have been divided into two categories. We have two experimental filter units, one 0.08 acre in area and one larger. Each of these filters are of the same depth and contain the same kind of stone as the 14 acres of filters included in the main plant. We have been working with DDT and "Ridbane," a new insecticide which is claimed to be less poisonous to warm-blooded animals.

The small experimental filter has been used to study the effectiveness of the larvacides applied in powder form. We have mixed the powders with talc and applied them at rates of 40 and 50 lb. per acre, these rates having been selected simply because Carollo has reported (THIS JOURNAL, **18**, 2,

208; March, 1946) that applications of 30 lb. of DDT per acre were not successful. These treatments have been found to affect the fly larvae quite successfully. The men who are conducting the work, however, indicate that there is also some effect on the film on the stone, as a sort of sludge deposit appears to collect on the surface during the first 24 to 48 hours after the application of either of the larvacides. This deposit soon washes away.

On the larger filters we have been using the DDT emulsion, applying it to the individual syphon chambers so that we might give a resting period to the beds. But because of the difficulties in applying it to seven 2-acre beds we had to discontinue that work. It took us 2½ days to apply it, so that there could be migration from one filter to the other during the experimental period. We still incline to think that, perhaps, dosage of the individual filters might be best but this can not be done under our conditions, so we have therefore confined ourselves for the balance of the experiment to its application just ahead of all of the syphon chambers.

The primary effluent in the Akron plant goes through a travelling screen for the protection of the nozzles. Just on the downstream side of this travelling screen we applied the DDT with a pump, and have varied the dosage from 0.25 to 0.5 p.p.m. and the hours of application from 1 to 12 hours.

We have observed that at the outer rim of the spray the larvae do not seem to be affected as they are on the balance of the bed. I think I could say we get a 99 per cent kill of larvae —at least as far as I can tell from visual observation. But this rim, which may be from 8 in. to 1 ft. wide, apparently does not receive a complete dose of DDT, and it is in that section that the complete kill does not take place. We find fly development to be much more rapid here than at the other places. To correct this condition we have tried application to the outer edges of the beds by means of a truck and spray, using 25 per cent DDT in fuel oil emulsion instead of coal oil.

Just one more observation. We tried dosage over different time intervals. We have come to the conclusion that for Akron, at least, we must dose every seventh day if we really want to have good control. That, by the way, happens to be the period we have been obliged to use at a small plant some twenty miles from Akron where we use flooding for control. These experiences indicate that the breeding cycle for our particular climatic condition is 7 days.

Morris M. Cohn, Sanitary Engineer, Schenectady, N. Y., and Editor, Sewage Works Engineering—The difficulty in securing the desired DDT application at the periphery of the filter is a basic characteristic of the distribution system, and this must be kept in mind in carrying on larvicidal efforts at any filter. This was brought out at Schenectady when we were studying chlorination as a fly control measure.

R. W. Simpson, Gilbert Associates, Reading, Pa.—I have had two years of successful experience with DDT for filter fly control in southern army plants. The cost of DDT—about 35 cents per gallon in 5 per cent emulsion —may be prohibitive, however, to some municipalities. Moreover, it may not always be advantageous to remove all of the fly larvae from the filter, since they are beneficial in controlling surface growths and ponding. I think a few larvae are to be desired, either in high or low rate filters.

Where it is desired to make heavy applications to a filter equipped with a rotary distributor, I have found that this can be accomplished very well by tying a rope to the end of the distributor arm and holding down the speed of rotation to the desired degree. Any rate of application within the range of the sewage flow can be obtained in this way.

Glass-Covered vs Open Sludge Drying Beds

George Phelps, Engineer of Sewers, Toronto—We are using glass-covered sludge beds at North Toronto and have found them an expensive means of handling sludge. I would say that their day is past in our climate. I would not consider putting them in again.

Wilfred G. Ure, City Engineer, Woodstock, Ont.—We have a glass-over bed at Woodstock and have found it costly to maintain. Also, the snow and ice that gathers on the roof in winter —the enclosure is not heated—slides down and takes glass and all with it. We had a lot of trouble this spring.

J. O. Corcoran, Commissioner of Works, East York Twp., Ont.—We have two activated sludge plants incorporating glass-over beds. These plants were constructed in 1926 with open sludge plants and we found them very unsuccessful. We had the usual type, and due to weather conditions we found we could not effectively dry the sludge.

In 1930 we installed glass-over drying beds with arterial drains and unit heaters to assist the drying of the sludge. Of course, the beds are designed so that the maximum amount of air is induced over the bed to create evaporation.

In 1942 we investigated the possibilities of cutting these drying beds out entirely and disposing of the wet sludge directly from the digesters. We found on investigating the cost that we could do it at a saving, and it has answered our sludge disposal problem.

Where sludge beds are used you have an accumulation of dried sludge that must be disposed of in some manner. We tried to ascertain its value as fertilizer and we found it was not high. However, there are a few townspeople and farmers who seem to think differently. Of course, we allowed them to take it away.

We now haul away the digested sludge in a wet state. The conveyance consists of a truck with a tank mounted on it. There is a special tailgate on the truck which is close fitting. The sludge is discharged into the tank, hauled away and disposed of on farm land in its liquid form. We have no further problem except that the local Board of Health insists that we do not put the wet sludge on ground upon which vegetables are to be grown.

R. A. Greene, Asst. Superintendent and Chemist, Jackson, Mich.—When our plant was built in 1936 we had four glass-over beds. In 1940 we built four more beds identical in size and construction with the original ones, except that they are open. Over a period of 4½ years, during which we operated both types with the same depth of fill, we had 165 dryings from the glass-covered beds and 156 from the open beds.

We sold our greenhouses this spring, figuring that the additional efficiency of a little less than 10 per cent did not justify the upkeep and expense on the glass-covered beds. If we build any more sludge beds they will be of the open variety.

C. C. Larson, Chemist, Springfield (Ill.) Sanitary Dist.—We have both glass-covered and open beds. I am sure we will never build any more glass-covered beds because we calculate that the cost is about four times as great. There are also times when we feel that the glass covering retards the drying of the sludge, so I feel that in our particular climate they are not justified.

Morris M. Cohn—Perhaps it would be well to get down to basics and say that there will be times when the glass-covered bed has an advantage and should be considered. There will be many instances in which mechanical sludge dewatering methods will be selected over atmospheric drying, but

where the latter is chosen there may be factors of a local nature that warrant the installation of glass-covered beds. There are time when the possibilities of control of atmospheric conditions on drying beds by covering them with some type of glass or other structure may be beneficial.

I also call attention to the fact that there are some plants in the country that are using sludge gas to heat enclosed drying beds. That may add the further advantage of year 'round atmospheric drying where it would be impossible on uncovered beds.

Linn H. Enslow, Editor Water and Sewage Works, New York, N. Y.—I agree with Mr. Cohn that climatic conditions may sometimes justify covered sludge beds; you must have some place to put sludge during extended periods of bad weather.

Durham, N. C. offers one answer to this problem. This plant does not have glass-covered beds but they do have a sort of airplane hangar roof which goes over a certain section of the drying beds—not all of them, just a part. A radiator grid has been installed underneath the sand bed and hot water from a gas engine cooling system is circulated through the grid. It is the heat coming up through the sludge that takes the water out, not just the heat on the surface. This method might be a real asset to many plants that have similar facilities available.

L. W. Van Kleeck, Principal Sanitary Engineer, Connecticut State Dept. of Health, Hartford, Conn.—I think not only has the closed bed its advantages for drying in bad weather conditions, but that it is also appreciated by the operator who must clean the beds in severe winter weather.

While the idea of odor control with the covered bed has been, perhaps, overrated, I think this is an advantageous feature. We have found that by controlling the ventilators, odors can be kept from reaching adjacent property.

One other advantage of glass-enclosed sludge beds is their attractive appearance. Several plants in Connecticut that are located in built-up areas are believed by some neighbors to be florist shops!

Thomas T. Hay, Superintendent of Sewage Treatment, Racine, Wis.—Our experience with the efficiency of glass-covered drying beds at Racine has been that the method of operating them will make a difference of over 20 per cent in drying time. Experiments made with sludges of representative quality and consistency have revealed that faster and more complete drying takes place when the ventilators are kept practically closed than when they are opened to permit circulation of air. My original idea was just the opposite, but some of my operators have proved to me that almost complete elimination of circulation is beneficial.

On some sunny days the temperatures inside the glass enclosures are 40° F. above the outside temperatures.

Irving Nevitt, Engineer of Sewage Treatment, Toronto—At the North Toronto plant the heating of the glass-enclosed beds is a major item in winter. When the plant originally went into operation we dried our sludge in summer in a period of 6 to 8 days. In the winter the drying time increased to 64 days. Our experience has been that the glass-covered drying bed is not particularly successful.

We tried to control the amount of air circulation by simply keeping the ventilators at the very top open to allow the moisture-laden air to dissipate, but this results in such heavy condensation that the water drops from the roof like rain and continues to wet the surface of the sludge. Consequently, we were driven some years ago to try and find some means by which we could accelerate the rate of drying, and we have found our best success with alum.

We apply the alum as a dry powder immediately behind a weir by which

we measure the amount of sludge going to the drying bed, and it goes through about three vertical passes of under-over baffles before it hits the surface of the bed. In doing so, we have found that our 64-day period of drying is now reduced to between 10 and 15 days. The average alum dosage is about 10 per cent, on the basis of the dry solids in the sludge.

Arthur H. Niles, Engineer-Superintendent, Sewage Division, Toledo, Ohio—We have perhaps one of the largest glass-covered sludge bed installations in the country. At the time the plant was designed vacuum filters were only in the laboratory stage and were not considered quite far enough developed to install them. That is why we have the glass-covered beds and we feel that they have served a very good and useful purpose.

We also have as an adjunct to our drying beds, what, I think, every plant should have—a marsh or lagoon to which excess sludge can be discharged. We have 200 acres which have been filled anywhere from 2 to 12 ft. deep in spots. We could fill it all probably to a depth of 12 ft.

We do not use the glass-covered beds in the normal way in which most sludge beds are operated. As long as we have this excess lagoon capacity, we decided to develop some fertilizer business, and the sludge put on the drying beds is kept there until it has a moisture content of less than 10 per cent. Sludge drying must be carried to this degree if you are going to sell it as fertilizer in bags, otherwise the bags will rot through.

The drying capacity of our beds, therefore, is much reduced. We get—instead of the normal, say, 12 dryings a year—about 2½ dryings annually. Bear in mind that the average moisture content of our digested sludge is about 8 per cent.

When we considered utilization of the glass-covered beds either as it was originally intended—to dry the sludge to 70 per cent moisture and then remove it—or use it for fill, or to make fertilizer, we decided on the latter. This choice is only possible, of course, because we are fortunate in having such excellent lagoon facilities.

Neglecting fixed charges, simply taking costs as beginning with the loading of sludge into the cars and considering everything beyond that such as power, maintenance, bags, selling costs, etc., we can show a profit of about $7,000 to $8,000 a year. Of course, when you consider that we have our beds located almost a mile from the plant where we have to keep watchmen the year round, that we do not use the beds after the middle of September because we would get into a condition where the sludge freezes, and the fixed charges on a $250,000 installation, our present system costs us over $33,000 a year. It depends entirely on the way you set up your bookkeeping as to whether you make a profit or a loss.

As far as Toledo is concerned, I am sure that we will never build any more glass-covered beds. However, I think that every sludge handling problem must be developed to meet certain local factors and that no universal rule can be established. We would have had an entirely different problem had it not been for our good fortune in having the marsh to use as a lagoon.

Question—Am I to understand that the exponents of open drying beds do not put out any sludge after the middle of September? If so, what do they do if they have no lagoon?

Mr. Niles—That is just our practice at Toledo. We do not put sludge on our glass-covered beds during the winter. We do not, of course, have enough digester capacity to store our sludge from September 15 to the middle of February or the first of March of the next year. We pump the digested sludge during the winter into this convenient marsh.

Sludge Dewatering Aids

T. C. Schaetzle—I am connected with one small plant which is limited in its sludge drying capacity. At the present time we are undecided as to whether to cover the existing beds or to build an additional open bed. The sludge at this plant appears to be no different than that produced elsewhere, being very black and containing 4 to 5 per cent solids. However, it takes about 3 months for it to dry.

We have tried treatment with alum and with lime and we have changed the underdrains—none of these things have helped and it has been necessary to resort to a lagoon. We have also tried drying of the sludge as taken from the primary digestion stage, and have had somewhat better results but not enough.

In our attempts at chemical treatment we have added them to the sludge just as it flows into the drying bed. The only other procedure left for us is to try more rapid mixing and agitation of the sludge after chemical application.

L. H. Enslow—Try baking powder. This is not as funny as it may seem, for in the alum treatment of sludge you achieve a flotation effect from the release of CO_2 by the reaction of the alum on the bicarbonates in the sludge. I suggest that you add some form of carbonate and apply the alum immediately thereafter and you will have the "baking powder" effect.

Comment—The percentage of solids is an important point when alum is used. If there is over 7 per cent solids, the water cannot be freed.

W. A. Sperry—In chemical conditioning, the sludge can be given too much agitation. While the percentage of total solids is a factor in the effectiveness of alum, the critical factor is the method of application. In the last 5 years at our plant careful application has given good results, whereas previously a gelatinous film was formed on the surface of the sand.

A. H. Niles—We made experiments on the application of lime, ferrous sulfate and ferric sulfate and found that with sludge of 12 per cent solids there was not a single day's difference in drying time.

Comment—Chemicals alone are not necessarily an answer to the sludge drying problem. It is important to develop CO_2 to get the flotation effect, but the mixing must be done in such a way as not to let the CO_2 go off too quickly. Another point is that not enough attention is paid to the kind of sand used for drying beds.

M. A. Groen, Superintendent of Sewage Treatment, Dearborn, Mich.—In Dearborn we have vacuum filters and our method of conditioning sludge is much the same as it is over the country generally—that is, with lime and ferric chloride. We have a very good and handy deposit of lime available in the form of carbide waste, which runs approximately 35 per cent available calcium oxide. We have to haul it ourselves, and we pay but 25 cents a ton for the lime at the pit.

Our rates of application in conditioning had been about 2 per cent ferric chloride and 8 to 10 per cent of calcium oxide until recently—about two months ago—the Electrical Chemical Corporation came out with a catalyzer that they have used in swimming pool water treatment and water purification and prevailed upon us to try it out in sludge conditioning. Our tests so far are incomplete but, by using very minute amounts of the catalyzer together with ferric chloride and lime, we find we can cut down the lime to less than 1 per cent from the original average of 10 per cent. The answer to Mr. Schaetzle's problem might be to add a few grains of this catalyzer to the sludge before it is put on the drying beds.

We have also made a few experiments involving addition of ground green garbage to our raw sludge and chemically precipitated sludge. We

ran a 100-ton test and found that the volatile content of the sludge cake increased from the 50 per cent average for sludge alone to about 75 per cent for raw sludge mixed with ground garbage. Rates of conditioning chemical application were the same as used for sludge alone, but we found that we operate the vacuum filters at a higher speed with the garbage-sludge mixture. The cake, however, had a higher moisture content.

The filter cake at Dearborn is incinerated. The higher volatile content of the garbage-sludge mixture gave more incinerator heat, but this was offset by the higher moisture content and greater incinerator heat requirements of the cake. The fuel value of the ordinary sludge cake is about 500 B.t.u. per lb. as compared to 1,500 B.t.u. per lb. for the garbage-sludge cake.

Our studies are being continued. We do not know whether we will end up with digestion or merely by adding the green garbage to the raw sludge and incinerating the mixture after vacuum filtration. We hope eventually to publish the results of our experimental work in SEWAGE WORKS JOURNAL.

BARK FROM THE DAILY LOG

BY W. W. MATHEWS

Superintendent, Gary (Ind.) Sanitary District

June 26—One thing about sludge suction lines—they will clog up! No. 4 primary tank refused to yield its contribution to the digester most of the day so it had to be dewatered. All on account of a mat of match-sticks, twigs and sand in the sludge hopper.

June 30—These raw sludge suction line stoppages must be contagious. This time it is No. 2 primary.

Recently we have experienced a practical demonstration of extreme wet weather operation. Rainfall this month totaled 7.72 inches, 7 of which fell during the first two weeks of the month. Precipitation in the 5-month period preceding was 3.38 inches below normal, allowing ground water levels to recede by infiltration to the sewers and giving a strikingly uniform daily pumpage of about 17 m.g.d.

Gary occupies a large sandy area and sand is usually found below the deepest sewers. The heavy rainfall early in June therefore submerged the sewer system in an underground lake, resulting in so much infiltration that pumpage rates reached a sustained peak of about 25 m.g.d. In addition to the loss of volatile solids at the overflows of the combined sewer system, the high flows carried sand, cinders, etc. to the extent that the volatile content of the raw sludge dipped to 36 per cent. As a result of the low volatile content of the raw sludge, gas production decreased from 190,000 c.f.d. to 67,000 c.f.d. So here we have the vicious cycle again—more flow and less gas.

Every activated sludge plant operator will agree that the dilution afforded by occasional periods of rainfall is highly beneficial. But there are times when it can be too much of a good thing. Especially when the high flows carry fine sand (passing a 100-mesh screen) and deposit it in the primary tanks, making it necessary to conduct a routine dewatering and hopper cleaning schedule until conditions return to normal.

We envy the operator whose sewer system is laid in clay soil!

July 1—But enough about our troubles. Here is a nice hot day with

everything going fine. The sludge beds are swarming with citizens who intend to try out this new fertilizer that can be had for the hauling, and they are clearing drying area that we can use to advantage right now.

July 8—After about six months of operation, the No. 2 gas scrubber has been given a new charge of iron sponge. The previous charge had removed 82,400 grains of H_2S per cu. ft. The sulfur content of digester gas here is fairly low, ranging from 22 to 45 grains per 100 cu. ft. in the raw gas. Scrubbing reduces this value to about 5 grains.

July 14—An interesting visitor today in the person of Gregorio de Leon, chief engineer of the Metropolitan Water District, Manila, P. I. He had been authorized to design two activated sludge plants to serve the city of Manila. (This was in 1941. We were sorry to learn later that, after operating the Manila water works throughout most of the war, Mr. de Leon was killed by the Japanese as they evacuated the city under the attack of General MacArthur.)

July 19—The blower pressure having built up to 9 p.s.i. (1 p.s.i. above the design value) a set of aeration tanks with clean diffuser tubes was put into service today. This is the third switch in aerators since the plant went into operation ten months ago. All available men (four) assigned to cleaning tubes.

July 22—Tight sewer joints and manhole connections are a "must" in Gary, otherwise a constant inflow of sand will take place. This morning we inspected a manhole on one of the District lines at which two small sewers had sheared off. The failure was discovered only after so much sand had entered the system that the pavement around the manhole had settled.

July 23—As a safety precaution, our attorney advised the Board at its regular meeting today that minors should not be permitted on the plant grounds without their parents or adult supervision other than District employees. The rule was made official by adoption of an ordinance. We would be interested to know if similar action has been taken elsewhere.

It is with deep regret that we note here the passing of Mr. Thomas O'Brien, an esteemed member of the District Board of Trustees. Mr. O'Brien's career is a fine example of what our nation offers an ambitious young man. Coming to the U. S. as an immigrant at the age of 19, he made his start as a helper in a Pittsburgh steel mill. Later he came to Elwood, Ind. as a tinner and progressed step by step until he retired in 1935 from the position of manager of the American Sheet and Tin Plate Company's mills.

July 24—Nostalgic amusement accompanies the notation of this 1941 item, a relic of the good old days: "Called Chicago this A.M. for packing—delivered in P.M."

The only difference now in securing delivery of maintenance supplies is that there is anywhere from 1 to 6 months between the A.M. and the P.M.!

July 28—Fair and hot—100° F. on the north side of the pump and blower building. Everyone was permitted to find a job in the shade.

August 1—A pleasant surprise was a visit by B. A. Poole, state sanitary engineer.

Not so pleasant was the finding that the insulation around one of the "down pipes" of the air compressors was being blown out into the discharge header. This accounts, of course, for an important part of the pressure rise in the air distribution system.

August 6—Installed the blower "down pipe" that had been sent to Chicago day before yesterday to have the insulation replaced. (Another good example of pre-war service.)

A temperature check at the blowers (Roots Connersville, positive displacement type) revealed some valuable in-

formation. The pressure drop across the bend was 1.5 in. of water at the rated speed of 400 r.p.m. The temperature at the top of the bend was 168° F. with the ambient temperature at 72° F. With the by-pass open, the temperature rise was 10° F. per minute. The test was stopped when the temperature reached 210 degrees.

The lesson here is "Don't wait too long before closing the by-pass and putting the load on the blower!" The reason for our insulation failure was that we had allowed excessive temperatures to develop, which resulted in charring of the mineral wool. Bronze wool was substituted for this material when the insulation was replaced.

Operators using similar blower equipment will please take note!

August 12—An experiment initiated, by the application of petrolatum to the cleaned diffuser tubes in four aeration tanks before they are replaced in service. Tests made at Cleveland indicate that greasing the exterior of the tubes increases the service period appreciably. The Chicago Pump Company, which furnished our tubes, tested several types of grease and found that petrolatum caused the smallest loss of head of those tested.

Our procedure was to warm the grease in a bucket until it reached the consistency of No. 10 motor oil; it is then applied in a thin coating with a paint brush.

August 20—The annual budget upon which we have been working for the last two months received its first test at a public hearing today. Indiana taxing bodies must publish a proposed budget twice and then submit it to three public hearings, the first for general objections, the second before the County Tax Adjustment Board and final one before the State Board of Tax Commissioners. The latter two Boards usually approve the budget if no objections are filed or presented at the hearings.

August 27—All good things come to an end, such as the period of trouble-free operation we have been enjoying lately. Our complacency was shattered on this occasion when the return sludge meter and one digester agitator decided to go out of commission at the same time. Then one of the men slipped down the outfall shaft at a final settling tank. No injuries, but a bad scare for all of us.

September 2—Two mysteries. Knowing how the digester piping was installed, we can't imagine how a piece of reinforcing rod could get into the drain valve of one of the units. It was there, though, because we had to remove it today.

The second enigma was easier to solve, although there was momentary indecision as to what was causing a patch of sand to act so strangely. Just an air leak where an underground blower discharge coupling had pulled apart. Easily fixed.

These little incidents are just like fleas on a dog—they keep an operator alert and scratching!

September 5—One of *those* days! About 2 A.M. a 4,200-volt underground power cable burned out and shut down the entire plant. New cable was obtained from one of the large industries and electricians worked hard all day and into the night stringing temporary lines. This was bad enough, but the worst repercussions came when closure of all regulators and opening of all diversion outlets to the river failed to keep enough sewage from the main interceptor to prevent flooding of about 50 basements just a short distance from the plant.

Some of the householders affected contacted us by phone; others called in person. Most of them did both.

The last straw came when we got the power turned on again at 10 P.M. An air compressor bearing immediately burned out, bending the piston rod in the high pressure cylinder.

Some fun!

September 7—The Grand Calumet River reached a stage above our overflow bulkhead and we started pumping it through the plant. Proved to be a bit more than we could handle, so we used a few sandbags to keep "Ole Man River" in his place.

September 9—When another main underground cable burned out at 11 A.M. today our experience of four days ago enabled us to go into action very quickly. In less than half an hour two utility service trucks were on the job and within an hour our truck had picked up a reel of cable and all the other replacement material needed. (We are fortunate in being close to several large industries which must keep large stocks of electrical maintenance materials.)

To make our cup run over—also the sewers—(to say nothing of the nearby basements), there were several heavy showers late in the afternoon. A bypass would have been deeply appreciated in such times as this, but our topography is too flat to permit bypass by gravity flow from the main interceptor. Everything that reaches it must be pumped.

When the power was restored at 9:15 P.M., the entire operating staff was worn out, not from manual labor but from nervous tension. It was a grand and glorious feeling to see the wheels begin to turn again!

October 13—We have been on a trip to Fort Wayne's attractive and efficient plant and a stay in New York City since our previous entry. It is hoped that there is no significance in the fact that everything went along in fine fashion during our absence.

The only problem at present is the weather. For the last week we have had 2 inches of rain every other day. The charts of the flow and gas production look like a profile of the Rocky Mountains!

The raw sewage B.O.D. hit a new low of 30 p.p.m. With 12 p.p.m. of B.O.D. in the final effluent, the percentage removal by the plant nosedived to 60 per cent. A combined sewer system has a sewage treatment plant operator at its mercy in times like these—especially when heavy filtration is encouraged by sandy soil and a high ground water level.

October 31—Another month like this and we will sprout web feet and fins! The total rainfall was 9.72 inches (normal for the month is 2.78 inches), giving us high flows, high dilution, high power bills and low efficiencies.

But there was not a single mechanical breakdown in the entire 31 days!

SLUDGE HEATING AND CIRCULATION BY DIRECT STEAM INJECTION

By C. P. Gunson

Superintendent, Sewage Treatment Plant, Denver, Colo.

For the past two years the sludge digestion units of the East Side and Main sewage treatment plants at Denver have been heated by means of the direct injection of live steam into the sludge. The results of the experimental and plant scale experience with this method of heating have been both surprising and gratifying.

Original Trial at East Side Plant

The idea of steam injection was developed first at the East Side plant, which was designed to afford primary treatment to a flow of 3 m.g.d. from Lowry Field and a new residential area of the city. The plant includes one 65-ft. digester that was not equipped with hot water coils because

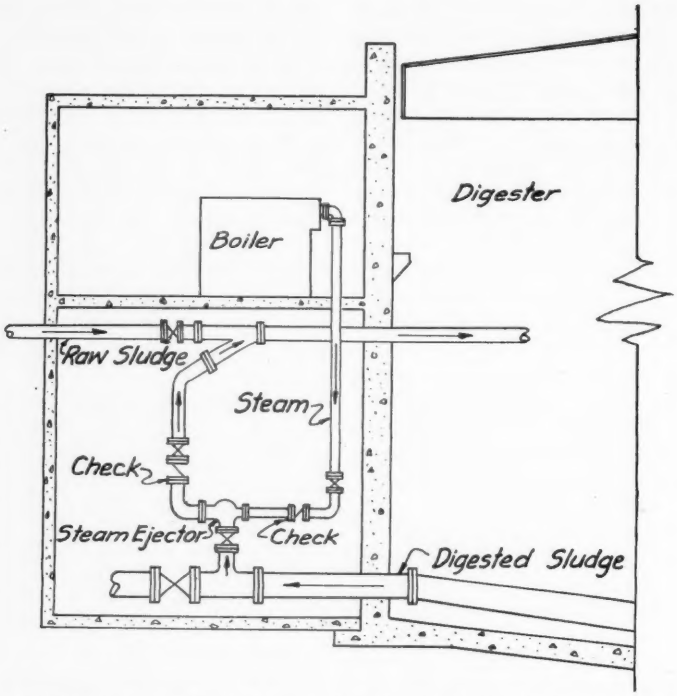

FIGURE 1.—Diagram of method of employing direct injection of live steam for heating of sludge digestion tanks at Denver, Colo.

it was intended to supply heat by the introduction of live steam into the raw sludge line at a point just outside the digester.

A pump was provided to recirculate sludge from the bottom of the digester so as to effect continuous heating. This arrangement required that the circulating pump be operated continuously during the times the boiler was in service. In an effort toward simplification and economy, an ejector was developed to replace the circulating pump, and was installed as indicated in Figure 1. This ejector was designed so that the nozzle was removable, making it possible to adapt to any size of boiler simply by inserting the proper sized nozzle.

The ejector arrangement functioned in completely satisfactory fashion. After eight months of observation it was decided to apply the method at Denver's Main plant.

Conversion of Main Plant Digesters

The Main plant has four digesters, each 85 ft. in diameter and 30 ft. deep. These units are equipped with heating coils and are served by individual boilers of 1,000,000 B.t.u. per hour capacity. Stage digestion is practiced, with two units used for primary digestion and the remaining two as second stage.

In the eight years of operation of the Main plant more and more difficulty has been experienced in maintaining the required temperature in the primary digesters. This has been due in part to the caking of sludge on the outside of the coils, and also to the high operating temperature sought.

In December, 1945, the two boilers provided for heating the secondary di-

gesters were converted from hot water service to steam. Ejectors were installed between the digested sludge and raw sludge lines at the two primary digesters, and the steam heating method employed to supplement the hot water coils in these tanks.

The digested sludge (transfer) lines draw from the bottoms of the digesters and the raw sludge lines discharge at the 14-ft. level—about mid-depth. At the boiler capacity of 1,000,000 B.t.u. per hour it was found that the ejector induced a sludge circulation rate of about 50 g.p.m.

Several advantages were gained by the location of the steam inlet at the point at which the raw sludge is introduced. First, the incoming raw sludge is uniformly seeded by admixture with partially digested sludge. Second, the raw sludge temperature is immediately raised, thus preventing cooling or chilling of any part of the digester contents, an item which is considered quite important. Finally, introduction of the warm, well-seeded sludge at mid-depth created a favorable environment for the digestion of any scum that might tend to accumulate.

It was found before steam heat was used in the primary digesters that each of them had developed quite a scum blanket. Soon after the heating system change these blankets completely disappeared and no further scum layers have been formed.

Operating Observations

During the past eight months this experiment has been watched very closely. Temperatures of the sludge from the digested sludge line together with the temperatures of the sludge leaving the ejector and entering the digester have been checked constantly.

After the digester temperature had been raised to about 100° F. considerable agitation became evident in the primary tanks. It was noted that the temperature of the sludge in the digested sludge line leading to the ejector varied downward over a 20° range. These low temperatures would sometimes hold for from 1 to 3 hours. The variation in temperatures lasted for about one week, after which the sludge

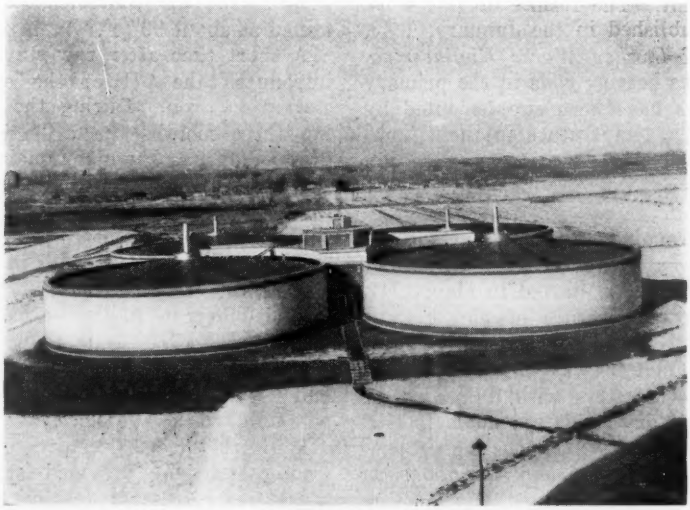

FIGURE 2.—View of four 85-ft. digesters at the Main sewage treatment plant, Denver, Colo. Control building in center.

temperature in the line leading to the ejector leveled off in the high range.

It was concluded from this observed variation in sludge temperatures that dormant pockets existed in the middle area of the digesters. This can be readily understood when larger diameter tanks are heated only by hot water coils located around the outer edge of the tank. The only circulation in the tank would be that induced by thermal action around the heating coils. The center of the tank would not be disturbed.

Samples were taken of the sludge circulated at the low temperatures. These samples consisted of a yellowish liquid containing few solids and having an offensive odor. It was estimated that about a fourth of the total digestion volume was occupied by the cold dormant pockets.

When the Main plant was placed in operation in 1938 it was generally considered that the optimum temperature for good digestion was between 80° and 85° F. In May, 1941, an experiment was tried whereby the temperature in the digesters was raised from 85° to 95° F. and maintained at this point. The results of this work were published in the January, 1943, issue of *Sewage Works Engineering*. Since the heating coils in the primary digesters have been supplemented by steam the temperature in these tanks has been raised from 95° to 105° F., which rise was gradual and highly beneficial.

As brought out in the article referred to above, covering the results of the experiments started in May, 1941, when a temperature of 95° F. was maintained, a 56 per cent reduction of volatile matter was obtained in the primary digesters with a loading of 4.9 lb. of dry solids per cubic foot of digester capacity. At the higher temperature (105° F.) and with thorough mixing and seeding by the circulation incident to the use of steam heat, a volatile reduction of 58 per cent is now achieved in the primary digesters, even though the digester loading has increased 25 per cent.

Temperature Control and Seeding Important

These studies have emphasized the well-known fact that bacterial action is affected sharply by environmental conditions. If the pH or temperature environment is changed to any great extent, the desirable organisms will be rendered ineffective until the proper environment is again established. Therefore, it is desirable that the incoming raw sludge be seeded and heated until the pH and temperature are as near as possible to that maintained in the digester. If this condition is adhered to, the bacterial life in the digester will be sustained in proper balance and at maximum activity at all times.

The importance of maintaining proper pH and temperature conditions was brought out very clearly when a new digester was recently put into operation. The unit was placed in operation in the winter months, heat having been provided so that the temperature of the contents was maintained at about 90° F.

A short time after raw sludge was introduced the pH of the contents started to drop. During the following three months the pH gradually dropped to 5.1 where it remained for the next 6 months. This digester was then seeded with a partially digested sludge to the extent of 10 per cent by dry weight of the raw solids in the digester, this seeding operation being extended over a 10-day period. The partially digested seed sludge had a pH of 7.2 and a temperature of 96° F., and its addition raised the pH of the new unit from 5.1 to 5.6.

With the proper temperature and seed environments provided for, it was considered necessary to adjust the pH factor into the desired range, and milk of lime was added until the digester

contents were brought to pH 7.2. This obviously satisfied the last environmental requirement because active digestion then took place, with the production of gas of high methane content. No foaming or other breaking-in difficulties were experienced and the digester has been operating satisfactorily ever since.

The effect of the introduction of a charge of cold raw sludge upon a heated digester is also of environmental significance, but in this case it is the temperature factor that is upset. The charge of cold sludge lowers the temperature in the region of the point of entry, and bacterial activity in that region is reduced until temperatures in the proper range are restored.

Summary

The sludge digestion tanks at the Denver sewage treatment plants have been successfully heated by the direct injection of live steam, this method being the sole means of heating at the East Side plant digester and being employed to supplement the hot water coils in the four large digesters of the Main plant. The steam is applied to the raw sludge feed line by means of an ejector that induces circulation of the digester contents.

This method of heating has been found advantageous in that it provides immediate seeding and heating of the raw sludge charge, and that it makes possible the maintenance of uniform temperatures in the desired range throughout the digester. More efficient digestion and control of the scum problem have been important results.

The steam heating procedure is substantiated in theory, since it satisfies the main environmental requirements of temperature and seeding, and holds these factors constantly in the range in which optimum bacterial activity takes place. By the maintenance of this favorable environment throughout the volume of the digester maximum use is made of the available capacity.

INTERESTING EXTRACTS FROM OPERATION REPORTS

CONDUCTED BY LEROY W. VAN KLEECK

Settle one difficulty and you keep a hundred others away.
—*Chinese Proverb*

Annual Report for the Fiscal Year Ending June 30, 1945 of the Richmond-Sunset Sewage Treatment Plant of the City and County of San Francisco, Calif.

BY JOHN J. CASEY, CITY ENGINEER

Heat Exchanger in Digester Repaired

After 6 full years of operation a leaking heat exchanger was removed from a Dorr turbo-mix type digester and the leak repaired after removing scale from the exterior of the coils. The scale was about ⅛ in. thick and consisted largely of calcium carbonate; the metal surface beneath it was found to be exceptionally free of corrosion.

Attention, Operators!: Superintendents of sewage treatment plants are invited to forward copies of their annual reports to Mr. Van Kleeck at the Connecticut State Department of Health, State Office Building, Hartford, Conn. for extracting in this section. Carbon copies of typewritten reports will be returned on request.

It is very probable that the other three heat exchangers have similar scale incrustations, to which the reduced heat exchange capacity of the system may be attributed.

Leakage of Sludge Gas from Digester Seal Eliminated

During the first four months of the year the average metered gas production was only about 0.4 cu. ft. per day per capita of connected population. This was caused by leakage of gas from the digester seal. On completion of a by-pass gas pipe line from the condensation trap in the boiler room to the gas meters, eliminating a portion of the line which had settled and allowed water to condense and form a trap, leakage of gas at the digester seal was considerably reduced. The metered gas production then rose to 160,000 cu. ft. per day, or approximately 0.9 cu. ft. per day per capita of connected population. (*Abstractor's note:* Unsupported gas lines frequently sag, causing this difficulty. Blessed is the operator with a pipe gallery in which all plant piping is accessible for inspection. Daily gas meter readings in any case are a valuable means of detecting gas losses.)

Elutriation and Sludge Filtration

All sludge withdrawn from the digester was washed with plant effluent in the elutriation tanks, resulting in an elutriated sludge with an average alkalinity of 450 p.p.m. This was a reduction of 80 per cent from the average alkalinity of 2,280 p.p.m. in the digested sludge.

All sludge from a population of 190,000 persons is dewatered on a single small vacuum filter of only 200 sq. ft. area, operating about 25 per cent of the total time. The filter cloth was replaced only twice during the year; the effective life of each cloth being about 1,000 hours of operation. The average ferric chloride dose on dry solids was 5.02 per cent, which is in excellent agreement with the computed value of 5.01 per cent by the equation for computing coagulant requirements developed by A. L. Genter (*Proceedings,* A.S.C.E., March, 1945, page 314).

Plant Enlargements Planned

Plans are now being prepared for two new 2,000-lb. chlorinators and chlorine evaporators. The present two thickening tanks will be enlarged.

Two new flocculation and sedimentation tanks will be constructed of the

TABLE I.—Summary of Operating Data for 1944–45, Richmond-Sunset Sewage Treatment Plant, San Francisco, Calif.

Item	Average
Population served, persons	190,000
Average daily sewage flow (m.g.)	
Treated flow (m.g.d.)	8.9
Screenings removed (cu. ft. total for year)	3,719
Grit removed (cu. yd. total for year)	1,260
Sewage solids (dry tons total for year)	2,858
Filter cake (wet tons total for year)	4,050
Dry tons total	960
Suspended solids (p.p.m.):	
Raw	260
Effluent	65
Per cent removal	75
B.O.D. (p.p.m.):	
Raw	230
Effluent	120
Per cent removal	48
Chlorine used:	
Pre-chlorination for odor control (lb. per m.g.)	30
Post-chlorination for disinfection (lb. per m.g.)	90
Gas produced per capita per day (cu. ft.)	0.9
Filter cloth life (hours of service per cloth)	1,000
Ferric chloride dose for sludge conditioning (per cent, dry basis)	5.02
Plant operation cost for year ($)	89,036
Per m.g. ($)	29.90
Per capita ($)	0.47
Raw sludge to digesters:	
Per cent dry solids	4.3
Per cent volatile dry solids	84.1
Digester temperature (F.°)	85.0
Digested sludge to elutriation tanks:	
Per cent dry solids	1.7
Per cent volatile dry solids	68.1
Per cent solids in elutriated sludge	3.3
Filter yield (lb. dry solids per sq. ft. per hr.)	5.2

same size as the present tanks. A new concrete superstructure will be built to house all the tanks. Structural glass blocks will be used with both natural and mechanical air change.

The present digester will be converted into a secondary digester. A new floating type cover to act as a gas-holder will replace the old fixed-type dome. A new 100-ft. diameter primary digester will be built. New type sludge mixers will be used.

The vacuum filtration system will be doubled in capacity. "Flash-type" sludge mixing will be used.

The piping arrangement in the elutriation system will be revised to permit single-stage washing of sludge transferred from the primary digester to the secondary, as well as two-stage washing of sludge from the secondary digester in preparation for vacuum filtration.

In order to remove existing cross-connections with the potable city water supply and to prevent any possibility of contamination of this supply, three independent water supply systems will be installed. The first, directly on the city water supply, will be used only for drinking water, showers and hand wash basins. In the second, city water will also be used for pump seals, flushing water, chlorinators, sprays, etc. after a physical break has been made from the potable water supply by a 12-in. free fall into storage tanks. There will be two storage tanks with booster pumps from the storage tanks to furnish the necessary pressures. The third system will be used to furnish plant effluent for water sprays in the settling tanks, pump seals and certain flushing connections. There will be no interconnections between the three systems. (*Abstractor's note:* This is a realistic approach to a hazard demanding more attention by designers than has frequently been evident in the past. A sewage treatment plant is the last place where a cross-connection with the potable water supply should occur. There are ways and means of preventing such connections—to wit, the proposed plans for alterations at this plant. There is no subject more worthy of consideration by a Federation committee than that of "Cross-Connection Elimination.")

Table I is a summary of the operating data for 1944–45.

Third Annual Report on the Sewage Treatment Plant of Dallas, Texas

By L. C. Billings, Supt. and Chief Chemist

General

In 1917 the first disposal system consisting of intercepting sewers, pumping plant, force mains and treatment plant of 12 Imhoff tanks and sludge drying bed was put into operation. In 1923 twelve additional Imhoff tanks were added to the disposal system along with the construction of an additional pumping station at Fair Park.

A modern treatment plant was put in operation in 1940 of such capacity as to serve 500,000 people. The estimated 1945 population of Dallas is 423,000. Figure 1 shows the flow diagram for the present treatment plant. This plant is of the trickling filter type having a capacity of 32 m.g.d. and built at a cost of $1,535,000.

Main Features

Bar screens are used. These are automatically raked and the screenings ground and returned to the sewage flow. Twin grit chambers have grit collectors and screw conveyors. Provision is made for blowing air, chlorinated air and introduction of iron salts as possible treatment of the raw sew-

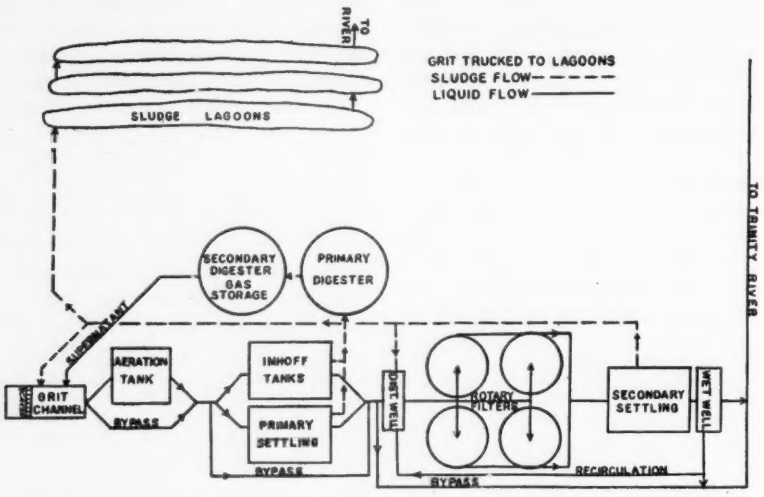

FIGURE 1.—Flow diagram of sewage treatment plant at Dallas, Texas.

TABLE II.—Summary of 1945 Operating Data at the Dallas, Texas Sewage Treatment Plant

Item	Average
First treatment plant went in operation (yr.)	1917
Present treatment plant built (yr.)	1940
Design population	500,000
Estimated present population	423,000
Miles of sewer	700
Capacity of plant (m.g.d.)	32.0
Cost of plant ($)	1,535,000
Expenditure for operation ($)	39,458
Cost per m.g. sewage ($)	5.01
Screenings, daily ave. (cu. ft.)	26.3
Cu. ft. per m.g.	0.85
Grit, daily ave. (cu. ft.)	89.0
Cu. ft. per m.g.	4.9
Settleable solids (ml. per liter):	
Raw sewage	10.2
Primary tank effluent	0.2
Imhoff tank effluent	0.5
Filter effluent	1.4
Final tank effluent	0.2
B.O.D. (p.p.m.):	
Raw sewage	317
Primary tank effluent	191
Imhoff tank effluent	206
Filter effluent	53
Final tank effluent	32
Dissolved oxygen (p.p.m.):	
Filter effluent	3.5
Final tank effluent	4.2
Sludge data:	
Primary tank settling:	
pH	6.3
Per cent dry solids	5.5
Per cent volatile dry solids	73.5
Transfer sludge:	
pH	6.9
Per cent dry solids	4.0
Per cent volatile dry solids	57.8
Secondary digester:	
pH	7.0
Per cent dry solids	6.6
Per cent volatile dry solids	51.8
Supernatant:	
pH	7.1
Per cent dry solids	0.7
Per cent volatile dry solids	53.7
Imhoff settling:	
pH	6.2
Per cent dry solids	4.1
Per cent volatile dry solids	76.8
Secondary tank:	
pH	6.7
Per cent dry solids	3.0
Per cent volatile dry solids	67.8
Trickling filter data:	
Loading, volume (m.g.a.d.)	3.83
Loading, B.O.D. (lb.):	
Per acre per day	7161
Per cu. yd. of stone per day	0.59
Per acre-foot per day	906

age for the purpose of grease removal and odor control.

The rectangular settling tanks, two in number, are each 80 ft. by 180 ft. by 11 ft. deep. The Imhoff tanks serve as the other section of primary settling.

The trickling filter area of 8.93 acres consist of 16 rock filters, 176 ft. in diameter and 7½ ft. in average depth. The filters are equipped with rotary distributors. Filters can be used in single or two-stage operation.

Final secondary sedimentation tanks are of the same type as the primary tanks. There are three units, each 50 ft. by 150 ft. by 11 ft. water depth. Sludge collectors are provided.

Separate sludge digestion is two-stage and limited in capacity for the plant. The two digesters are each 85 ft. in diameter by 30 ft. in depth. The primary digester is equipped with a Turbo-mixer.

Recirculation pumping capacity (of secondary tank effluent) is 35 m.g.d.

Operation

Primary tank sludge was pumped twice per day. At first the arrangement called for one pumping on the morning watch and one on the evening watch. Later the morning pumping was set up for early on the day shift. Seventy per cent of the primary tank sludge was put into the digester; the remaining 30 per cent, being thin sludge, was pumped to the lagoon. The average length of sludge pumping period was 1¼ hours per day. All Imhoff tank sludge was lagooned.

Recirculation of plant effluent to the filters was used only at periods when the raw sewage was by-passed. The purpose of this was to keep the filter stones moist in order that organism deterioration could be prevented or delayed. The total time of recirculation for the year amounted to approximately 75 days.

Industrial wastes impose a heavy and variable load on the plant. The wastes include those from packing-houses, cotton seed oil plants and from soap manufacturing, dairies, garages, etc.

Table II gives a summary of the 1945 operating data.

Special Report by the Bureau of Engineering of the City of Los Angeles on the Disposal of Sewage Sludge as Fertilizer

The pertinent findings of the Bureau given in a special report dated October, 1945 are of interest in showing the continued trend in California for utilizing sewage sludge as fertilizer rather than burning or otherwise wasting this by-product of sewage treatment. The report applies particularly to proposed operations at the Hyperion sewage works.

The quantity of sludge estimated by digestion and raw sludge production is:

(A) Digested sludge: 150 tons per day initial and 200 tons per day ultimate, which equals 54,750 tons per annum initial and 73,000 tons per annum ultimate.

(B) Raw mixed sludge: 278 tons per day initial and 371 tons per day ultimate, which equals 101,470 tons per annum initial and 135,415 tons per annum ultimate.

The conservative assumption of the fertilizing properties of the sludge would be:

(A) For digested sludge—nitrogen 2 per cent, phosphates 1 per cent.

(B) For raw mixed sludge—nitrogen 4 per cent, phosphates 2 per cent.

The estimated value per ton of sludge is:

(A) For digested sludge: $7.00 per ton.

(B) For raw mixed sludge: $14.00 per ton.

These unit prices per ton would yield on a yearly basis for the quantities estimated above:

(A) Digested sludge: from $383,250 to $511,000.

(B) Raw mixed sludge: from $1,420,580 to $1,895,810.

It is further concluded that there are in this market dealers who would be prospective bidders for this material and who are fully equipped to remove 300 to 400 tons per day from the plant, so that barring unusual interruptions, haulaway of the sludge could be considered as being reasonably constant, involving no problem of extensive storage facilities.

1945 Annual Report on the Akron, Ohio Sewage Treatment Plant

By T. C. Schaetzle, Supt.

Type of plant

The treatment of sewage at Akron includes coarse and fine screening, grit removal, Imhoff tanks, trickling filters and final settling. Separate sludge digestion is also employed. Most of the sludge produced is lagooned.

Effects of Rubber Wastes

Nothing special was done about the rubber companies' wastes until midsummer when we plotted the flow, rainfall, suspended solids and B.O.D. data for the raw sewage for the periods prior to, during and after the various rubber plant shut downs. These curves showed distinctly that the rubber wastes materially affected the sewage. Copies of the curves were forwarded to each of the companies. This was followed by a series of conferences with officials representing each rubber reclaim plant, inspections of these plants, and the forwarding of a letter to officials of each of the companies stating the problem, the seriousness of it with respect to future expansion and the need for real cooperation on the part of each rubber company.

No sampling worthy of mention was done at the reclaim plants but during November and December float tests were made to determine the time of travel from Firestone, Goodrich and

TABLE III.—Summary of 1945 Operating Data at Akron, Ohio

Item	Average
Treated daily sewage flow (m.g.d.)	51.7
By-passed daily flow (m.g.d.)	1.03
Screenings per m.g. sewage:	
Bar rack (cu. ft.)	0.49
Dorrco fine screen (cu. ft.)	1.65
Grit (cu. ft. per m.g.)	7.26
Grit analysis:	
Per cent moisture	50.3
Per cent volatile matter	32.1
Imhoff tank data:	
Suspended solids:	
Influent (p.p.m.)	312.0
Effluent (p.p.m.)	142.0
Total cu. yd. sludge removed	260,473
Sludge analysis:	
Moisture (per cent)	93.1
Volatile matter (per cent)	62.3
pH	6.0
Trickling filter effluent:	
Suspended solids (p.p.m.)	133.0
B.O.D. (p.p.m.)	52.2
Relative stability (%)	56
Humus tank effluent:	
Suspended solids (p.p.m.)	72
B.O.D. (p.p.m.)	31.7
Dissolved oxygen saturation (%)	40.3
Relative stability (%)	71
Sludge gas (millions of cu. ft.):	
Produced	5.33
Wasted	1.03
Separate sludge digestion sludge data:	
Per cent moisture:	
To primary	91.6
From secondary	92.9
Supernatant	99.2
Per cent volatile:	
To primary	65.6
From secondary	56.1
Total expenditures for year ($)	92,083
Cost of treatment per m.g. ($)	4.96

Goodyear to the plant so as to tie up the "slugs" of reclaim received with the company discharging them. These float tests were completed except for high flow periods for Firestone and Goodyear.

Table III is a summary of the 1945 operating data.

Annual Report on the Sewage Treatment Plant for the City of Jackson, Michigan for the Fiscal Year Ending July, 1945 *

By A. B. Cameron, Supt.

Experiments with Thermophylic Digestion

The operation of the digesters for the past year was satisfactory as a whole but the sludge was thinner than is expected in the future. As noted in the last two yearly reports we have been conducting extensive experiments and research on thermophylic digestion. This work was finished in November, 1944 but it took some time to adjust the digesters again to mesophylic digestion. Also, some of the tanks had to be emptied, coils scraped, etc. all of which delayed getting these devices back to normal operation, and will account for the relatively poorer than normal results obtained from these processes.

* For previous extracts see: This Journal, **16**, 5, 995 (Sept., 1944); **17**, 4, 837 (July, 1945).

TABLE IV.—Summary of 1945 Operating Data at Jackson, Mich.

Item	Average
Connected population	50,000
Sewage treated (total m.g.)	2,938
Daily flow (m.g.d.)	8.16
Air consumed (million cu. ft., total)	1,786
Gas produced (thousand cu. ft., total)	21,552
Gas wasted (thousand cu. ft., total)	6,571
Gas used (thousand cu. ft., total)	14,981
Dry solids removed (tons, total)	2,546
Cost of operation (total dollars)	49,698.17
Per m.g. sewage ($)	21.58
Chemical analysis:	
Raw sewage:	
Suspended solids (p.p.m.)	230
B.O.D. (p.p.m.)	160
Settleable solids (cc. per liter)	3.9
Dissolved oxygen (p.p.m.)	1.9
Organic nitrogen (p.p.m.)	8.3
Oxygen consumed (p.p.m.)	53.0
Final effluent:	
Suspended solids (p.p.m.)	15.0
B.O.D. (p.p.m.)	4.0
Dissolved oxygen (p.p.m.)	5.8
Organic nitrogen (p.p.m.)	2.5
Oxygen consumed (p.p.m.)	8.0
Suspended solids, mixed liquor (p.p.m.)	2,594
Per cent of sludge returned	11.0
Sludge index	44
Reduction in digesters:	
Total solids (%)	28
Organic solids (%)	44
Suspended solids reduction (%)	94
B.O.D. reduction (%)	97

Item	Average
Raw primary sludge (1,000 gal. per day)	33.2
Return sludge (m.g.d.)	1.16
Air used (cu. ft. per gal. sewage)	0.6
Solids (per cent by volume):	
Return sludge	94.0
Mixed liquor	11.0
Gas production per capita per day (cu. ft.)	1.17
Dry solids removed per capita per day (lb.)	0.28
Grit removed (cu. ft. per m.g.)	0.60
Dry sludge removed (cu. yd., total)	5,619
Per cent carbon dioxide in sludge gas	31.0
Grand River dissolved oxygen (p.p.m.):	
Above plant	7.4
Below plant	7.6
Primary sludge:	
Per cent solids	5.2
Per cent volatile solids	64.0
Return sludge, solids (%)	1.8
Supernatant suspended solids (p.p.m.)	9,138
Digested sludge to beds:	
Per cent solids	5.9
Per cent volatile solids	49.0
Sludge cake solids (%)	35.0
Digester temperature (F.°)	81.0
Digester pH	7.1
Digester contents, alkalinity (p.p.m.)	2,812

A detailed report of this work was published in the May, 1945, issue of SEWAGE WORKS JOURNAL, but very briefly this may be summed up as follows. It was found that from 1.6 to 2.0 times as many pounds of volatile solids could be digested in the same capacity tank when using thermophylic digestion, and that the resultant sludge dewatered reasonably well and was fairly concentrated. This, of course, is of great interest to plants that are overloaded at present and to future large plants. The thermophylic digestion process is much more difficult to control and probably should be limited to large or medium size plants where competent technical personnel is employed. We do not plan on using the process at present, as we have ample digester capacity to operate satisfactory in the mesophylic range.

A summary of the 1945 operating data is given in Table IV.

AN INVESTIGATION OF METHODS OF SLUDGE REMOVAL AT DRYING BEDS

BY WALTER M. KUNSCH

Engineer-Manager, Urbana and Champaign (Ill.) Sanitary District

When built in 1923–24, the sewage treatment plant of the Urbana-Champaign Sanitary District included twelve open sludge drying beds equipped with an industrial railway system for removal of dried sludge. This layout was expanded in 1932 by the addition of five beds, into which the track system was extended.

Two trains of three ¾-cu. yd. industrial dump cars were used in cleaning the beds, one train being loaded while the other was being hauled to a dumping platform where the cars were emptied into a truck for removal to the stock pile ¼ mile away. The cars were pulled by horse, seemingly a primitive method but actually a practical one in this case. The District owned two horses and they were used to good advantage when not hauling sludge for mowing the 47-acre grounds, hauling grit and rubbish, and similar purposes. All things considered, the horses were undoubtedly more economical from the standpoint of investment and upkeep than would have been an industrial locomotive that could have been used only for moving sludge.

As performed with the industrial cars, the sludge bed cleaning operation required at least six men. Four men were required to load the cars, one to drive the horse and one to drive the truck. Usually three of the loaders and the truck and driver were hired by the hour for each cleaning of the beds, the remaining two men of the crew being regular plant employees. The District did not own a truck and it was advantageous, when possible, to arrange with farmers to provide trucks to haul for their own use directly from the dumping platform.

By 1944 it had become so difficult to secure extra labor for sludge bed cleaning that the lack of adequate crews delayed the work and interfered with digested sludge withdrawal. Often the night shift operators would come to the rescue and work a double shift of 16 hours for as long as six consecutive days, in order to get the beds cleaned. Many times only three or even two loaders were available. This overworked the men and made the system inefficient and expensive, as the teamster and truck driver would stand idle while waiting for the cars to be loaded. Costs for extra labor and truck hire rose from 21.8 cents per cubic yard of dried sludge ($1.49 per

ton dry solids) in 1941 to 31 cents per cubic yard ($2.36 per ton dry solids) in 1944.

These labor difficulties and cost considerations led to a review of other methods of handling dried sludge at the beds, as the basis for recommendations to the trustees of the District. The analysis may be of interest to other operators.

Methods Considered

Any new equipment purchased to replace the original sludge removal method must be such that two men, or even one man if necessary, can load sludge and haul it, without additional help, to the point of disposal or storage. This condition can be satisfied only by the use of a dump truck or side-bin tractor for direct hauling from the beds to the dumping area. Major consideration was given to the use of these two types of equipment.

Some consideration was given to the use of an overhead scoop loader or a bucket elevator, but the use of either of these devices seemed impractical for the following reasons: (1) It would be necessary to purchase a truck as well as the loader to haul the sludge from the beds, involving a total investment of $4,000 to $5,000. (2) Both the overhead loader and the bucket elevator have proved unsuccessful in practice because they remove an excessive amount of sand from the bed. (3) In dry weather the operation is very dusty and when the sludge is somewhat wet, as is often the case in spring, dumping is retarded by the stickiness of the sludge. (4) In the case of the bucket elevator the lumps of sludge are often too large to be handled.

Removal by Side-Bin Tractor

The "side-bin" tractor is used for sludge removal at Springfield, Aurora, and Decatur, Ill., and at Mansfield, Ohio. It is reported from these plants that the use of the tractor is successful and economical. Sperry at Aurora is especially enthusiastic and claims that the tractor has been the salvation of the plant in periods of labor shortage, since much of the sludge removal is done by one or two men using this equipment. He has reported a reduction of 40 to 50 per cent over the cost of removal by the industrial car and track method.

Decatur and Springfield have both a tractor and truck available for sludge removal. Each type of equipment has its advantages. The type used at any particular time depends very much on the condition of the sludge and of the ground, that is, whether wet or dry, and on the length of haul. Hatfield of Decatur states, "The two-yard dump truck is faster for long distance hauls but requires the laying of plank runways on the bed to keep the double tires from sinking into the sand. The tractor holds 3 cu. yd. but travels only 6 to 10 miles per hour. I find the men prefer the tractor because of the planking mentioned above." He also claims, "We use the tractor to grade roads, pull out trees and build dikes for our lagoon sludge; it is one of the handiest pieces of equipment we have."

The tractors used are powered by gasoline motors of about 30 h.p. rating. The two sludge bins are hung directly from the chassis, and have a capacity of about 1½ cu. yd. each. The dumping doors open outward, the weight of sludge aiding in their operation. The control is at the driver's seat. The loading edge of the bin is low enough so that the heavy sludge can easily be loaded by hand.

The tractors weigh about four tons, equipped with the bins. When fully loaded the tread pressure on the sand is only 9 to 10 lb. per sq. in., which is no more than that of a man walking over the sand. With the bins the tractor is about 8 ft. long, 7 ft. wide and 6 ft. high.

One of the great advantages of the tractor is its maneuverability. It can

be backed straight into the beds and driven straight out, causing practically no disturbance to the sand surface. When driven down the center of the Champaign-Urbana beds (which are 25 ft. wide) it would be within easy loading distance of any portion. When necessary the tractor can be turned in its own length. This would prove valuable in reducing alterations necessary outside the beds. The flexibility of the tractor would permit placing the sludge on the dump or at any other location, regardless of soil conditions. The tractor can climb over the sludge already dumped with no difficulty, and thus can be used to build the stock pile to any desired height. Care would have to be exercised, however, in driving over a thick layer of wet sludge. A tractor, once stuck in this material, is extremely difficult to remove.

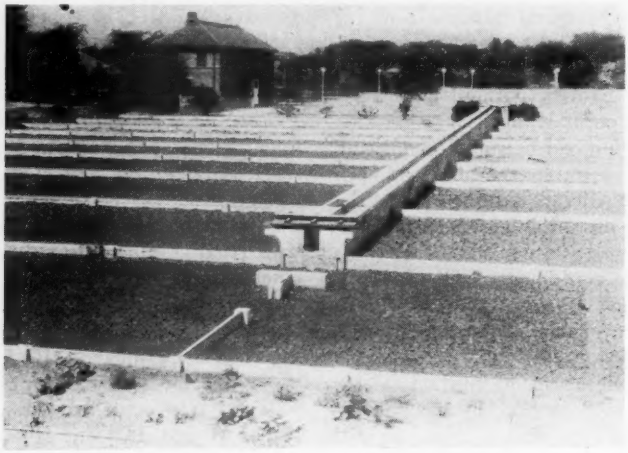

FIGURE 1.—View of sludge drying beds at sewage treatment plant of the Urbana and Champaign (Ill.) Sanitary District

Removal by Truck

Several plants which use trucks for sludge removal were contacted. As previously mentioned, Decatur and Springfield have both truck and tractor available. At Oshkosh, Wis., all sludge is removed by truck manually loaded. At this plant concrete runways are provided in each bed so that there is no difficulty in entering or leaving the bed with the truck. Supt. R. W. Frazier claims that the arrangement is ideal.

Worcester, Mass., uses an overhead loader and truck but at that plant the drying beds were converted from slow sand filters with an original depth of 30 in. of sand, so that loss of sand is not a vital consideration. Also, the sand is of such compactness that the truck can be driven directly on the surface without sinking in.

Hatfield at Decatur reports that planking must be laid in the beds when the truck is used.

It appears that the main consideration in using a truck is that a safe entry and runway into the beds must be provided. The truck can be used for longer hauls than the tractor. While it cannot be put to use in pulling stumps and grading roads, it would in most cases be of value for miscellaneous jobs, such as hauling grit, sand for the beds, tools and equipment for sewer and siphon cleaning, and other work.

In considering the purchase of a

truck, special bodies were investigated and the most practical seemed to be one with hinged sides, by the use of which the loading level would be comparable to that of the industrial cars. This would make for easier and faster loading.

With planks being used as a runway for the truck, the track system could be left intact if it were found desirable. The eight beds on the north are provided with a good cinder road at the entrance so that no road alterations would be necessary there. The nine beds on the south, however, would have to be provided with entrance drives. These drives could eventually be constructed with the regular crew but until such time it would be necessary to continue using the dump cars for that section of beds. The District truck, in such case could be used for final disposal, thus saving the cost of outside truck hire.

Costs

Side-Bin Tractor

Under the war conditions prevalent in 1944, the only suitable tractor model available was the TD–6 International, which is driven by Diesel fuel. This model would have cost about $2,600 without the side-bins, which were estimated at $600. (The side-bins for the Decatur tractor were obtained for $500 in 1942.)

Based on a 10-year life and an assumed scrap or trade value of $300 at the end of that time, the annual depreciation charge on the tractor would be $290. Using the $70 annual operation cost and $20 insurance charge experienced at Aurora, the total yearly cost of the tractor would become $380.

Truck

The only truck model for which definite costs were obtained was the International K–5 with 159-in. wheelbase. Rated at 1½ tons, this truck will carry a 5-ton payload without difficulty. A quotation was also secured on a Model D–12, hinged side, Anthony body and hoist to fit the International chassis. The truck at $1,302 and body at $558 brought the total cost to $1,860.

Based on an estimated trade value of $260 after 8 years of use, the annual depreciation on the truck assembly would be $200. With gasoline, oil and repairs at $100 per year and insurance at $20, the total annual cost would be about $320.

Other Conversion Costs

The salvage value of the industrial track was considered adequate to cover the cost of removal. The seven dump cars would also have some salvage or resale value, because they had always been kept in good paint and mechanical condition.

Removal of the track would be essential if the side-bin tractor was used. In addition, about 230 ft. of 10-ft. gravel road would be required to serve the south eight beds. The gravel required for such a roadway would cost about $75.

If removal by truck were adopted, the industrial track could be retained for emergency use, and heavy planking costing about $40 would be required to permit access into the beds. Entrance drives to the south beds would have to be provided. Assuming that this work might be performed in the fall and winter months by regular plant personnel, the cost of gravel at about $175 would be the main item.

Summary of Analysis

As a result of the above study, a recommendation was made to the District trustees that the purchase of a suitably equipped truck be authorized, together with the incidental changes necessary to permit the use of the truck in cleaning sludge beds. The following points were offered in support of the recommendation:

1. Continued dependence upon the industrial track system for removal of dried sludge would be detrimental to

the operation of the entire treatment plant because of the current and future scarcity of labor.

2. The provision of either a truck or side-bin tractor would permit removal of dried sludge directly from the beds with as few as two men instead of the five or six men required with the industrial railway system.

3. The immediate investment required for the side-bin tractor would be approximately $3,250 and the annual cost would be about $380.

4. The immediate investment in the truck, including roadway changes, planking, etc., would be about $2,000 in addition to which permanent concrete runways in the existing beds would cost about $1,000 to be spread over several years. The annual cost of the trucking procedure would be about $320.

5. To offset the cost of equipment and alterations, a saving of at least $550 per year would be realized by the elimination of truck hire and the teamster.

6. Aside from the initial investment and annual cost considerations, the truck would be more advantageous than the side-bin tractor because of the miscellaneous uses to which it could be put in connection with the operation of the plant.

Outcome of Investigation

In compliance with the writer's recommendation, the District trustees approved the purchase of a truck in September, 1944. After struggling through the red tape of WPB, OPA, and truck and body shortages, a 1½-ton International K–5 truck, with an Anthony low side-height body, was delivered in June, 1945. The truck has been used since that time for loading and hauling all sludge from the beds. Fortunately, it has been possible to drive the truck, without planking, on the sand. Unusually dry summers and autumns, as well as a good deal of care by the drivers, has to date permitted this method of operation. It is realized, however, that fundamentally this is poor practice, and plans are being made to begin and complete concrete runway construction during 1947 and 1948.

The two horses formerly used for pulling the industrial cars have been sold, relieving the operating staff of their care. This has proved to be an important advantage resulting from the change in sludge removal procedure.

While at this time no definite figures are available, the minimum savings calculated in the foregoing report have been more than realized. Outside truck hire and the employment of extra labor for the purpose of hauling sludge has been entirely unnecessary. Other than that, the truck has proved invaluable for a myriad of purposes in maintaining the treatment plant and intercepting sewers.

TIPS AND QUIPS

A Moan About Ammonia

A strong ammonia odor during the night and early morning hours at the screen house of the sewage treatment plant of the Urbana-Champaign (Ill.) Sanitary District caused no particular concern until it had persisted for four days, by which time strange things began to take place in the plant. Armed with a pH kit and a keen olfactory sense, Supt. Walter M. Kunsch made a tour along the intercepting sewer, which eventually led him to the source of the ammonia.

A recently established egg freezing factory had ordered a tank car of liquid ammonia for its refrigerating system. When only about 30,000 lb. of the 53,000 lb. in the car proved sufficient for this need, the remainder of

the ammonia was bubbled into a barrel of water and the solution discharged to the sewer. This wastage was begun on a Saturday and was practically complete when it was traced down the following Wednesday.

Some of the effects of the resulting high concentration of ammonia in the sewage were as follows:

1. The sludge removed from the primary tanks became very thin, dropping from about 6 per cent solids to 3.5 per cent. The quantity of solids removal by primary sedimentation also decreased markedly from the usual value of about 3,500 lb. dry solids per day to a low of 1,560 lb. per day.

2. Gas production at the digester zoomed from about 30,000 cu. ft. per day, the normal average, to 44,000 cu. ft. per day. The gas production gradually fell off after the peak was reached, on account of the decreasing raw sludge charge, but stayed above normal in spite of the fact that the raw solids were reduced to less than half their normal quantity. Production of gas per pound of volatile matter added to the digester jumped from the usual 13 cu. ft. per pound to 26 cu. ft. per pound on the fourth day of ammonia reception. It remained above 20 cu. ft. per pound of volatile solids added for the next four days. (A sort of uncontrolled "controlled digestion" as it were.)

3. The heaviest trickling filter slough in the recent history of the plant occurred, lasting for about two weeks after the ammonia was received. The slough was notable for the extraordinary exodus of worms from the filter —almost all of them dead.

Nitrogen determinations are not included in the routine analyses made at the plant, so no data are available on the ammonia concentrations that were present while the chemical was being wasted. Assuming that the crude solution barrel was only 50 per cent efficient, the average ammonia concentration added to the sewage is estimated at about 75 p.p.m., although it is certain that peak concentrations were much higher. The alkalinity of the raw sewage, normally 80 to 100 p.p.m., increased to a high of 1,700 p.p.m.; the alkalinity of the plant effluent was 1,100 p.p.m. at the peak.

After receipt of the ammonia-laden sewage had ceased, the primary sludge consistency returned to normal almost immediately and gas production followed about a week later. The unloading of the trickling filter, however, continued for about a month, leaving that unit in excellent condition. Removals by the filter since the unloading have been unusually good.

Sunshine and Sludge Drying

At Toledo, Ohio, where glass-covered sludge drying beds are used to dewater digested sludge to a degree permitting it to be bagged and sold as fertilizer, Supt. A. H. Niles looks upon each day of sunshine as money in the bank. He attributes the near-record production of 1,370 tons of Tol-e-Gro in 1946 to the fact that there were 2,563 hours of sunshine in the year, and contends that sunshine is a more significant factor than temperature in air drying under glass. The following comparison between hours of sunshine and dried sludge production at Toledo generally supports this theory:

Year	Sunshine (hrs.)	Fertilizer Production (tons)
1946	2,563	1,370
1945	2,174	1,152
1944	2,222	1,123
1943	2,385	1,166
1942	2,290	1,158
1941	2,377	1,379
1940	2,237	949

The 1946 annual report for Toledo shows that Tol-e-Gro processing costs (exclusive of general overhead and fixed charges) have slightly more than doubled from the $2.03 per ton figure

in 1941. These costs have risen steadily to $4.13 per ton in 1946. Consideration is being given to an adjustment in the selling price schedule that has been effective since 1943. The average selling price per ton in 1946 was $9.87.

Winter Performance of Open and Housed Filters

An interesting study of trickling filter operation was undertaken last winter at Grafton, N. D., where the sewage treatment plant includes both open and housed filters. Ordinarily, because of the severe winters in this area, the open filters are cut out of service during extreme cold weather. They were kept in operation this year at the suggestion of the State Department of Health so that results could be compared with those effected by the enclosed filter.

With 95 per cent of the open area covered by heavy ice formations, the effluent B.O.D. averaged 58 p.p.m. as compared to 48 p.p.m. for the covered filter effluent. The over-all reductions through the parallel plants were 68 per cent for the open and 73 per cent for the covered filters. Temperatures ranged from 10° above to 20° below zero during this period of study.

During January, with about half of the open filter iced over, its efficiency was comparable to that of the enclosed unit. The open bed operated at higher efficiency in November, when temperatures ranged from 20° to 40° above zero.

This brief summary of the study was reported in the February–March, 1947, issue of the North Dakota *Official Bulletin*. A more detailed report is in preparation.

Experts Aid Illinoisans

Something new in operation clinics was tried with considerable success when the Illinois Sewage Works Operators' Conference was held in Springfield last November. On the premise that open discussions often stray afield of the topic at hand, it was felt that it might be well to set up groups of "experts" in various phases of plant operation and let the operator having a problem discuss it across the table with these men serving as consultants.

Three experts in each of fourteen elements of plant operation were established in separate, placarded locations about the large meeting room. Those having specific problems were thus able to present them directly and to secure suggestions from competent authorities.

The plan is considered to have worked out very well. It was noted that even a few operator-experts took advantage of the opportunity to obtain counsel and solace at stations other than those to which they had been assigned.

Paint Kit Note

Good paint brushes are scarce and expensive, and lack of proper care between paint jobs ruins many more of them than should be the case. "Logger" Walter A. Sperry passes on these suggestions for preserving brushes:

1. After use, wash the brush thoroughly in gasoline and then with hot water and soap.

2. Keep the cleaned brushes in a mixture of one part turpentine and nine parts raw linseed oil. The turpentine prevents "skinning" and "fattening" of the oil, and the evaporation rate is low.

3. To prevent bending of the bristles it is desirable to suspend the brushes in the oil-turpentine mixture. A metal brush box in which the brushes can be hung on a metal rod passed through a hole in handle is recommended.

A turpentine rinse is all that is needed to prepare for use a brush that is given the above care.

Shock-Proof Filters

Supt. D. E. Henn of the De Kalb (Ill.) Sanitary District has long been

a ready witness to the ruggedness of the trickling filter under unfavorable loading conditions. He finds opportunity to strengthen his opinions in this respect in describing in his 1946 annual report an incident in which the De Kalb filters were subjected to a repeated shock dosage of zinc cyanide solution.

It seems that a peaceful Sunday morning in December was disrupted by complaints of fish destruction in the river below the plant outlet and by the observation that the trickling filters were disgorging huge quantities of dead worms. The pH of the raw and treated sewage was at the unusually high value of 8.0. By the next morning the river conditions apparently were improving, dissolved oxygen concentrations being found to range from 2.6 to 6.9 p.p.m. Digester gas production had dropped overnight, however, from 11,000 to 3,500 cu. ft. per day. The top filter stones were completely cleaned of growths and unloading was continuing at a high rate.

A strong toxic poison of high alkaline reaction being indicated, a search was made for the source, which proved to be a small metal plating plant which had only recently located in the city. It was found that this plant had been engaged in test runs the week before, and that discharges of about 300, 200 and 600 gal. of a strong caustic solution of zinc cyanide had been dumped to the sewers between Wednesday and Saturday. The proprietors of the plant readily cooperated by agreeing never to discharge this waste to the sewers in the future.

Supt. Henn finds great satisfaction in the fact that the trickling filters, although knocked badly out of biological balance by the cyanide wastes, came back to normal operating efficiency within a week of this incident. An 0.8-inch rain three days after the last discharge of wastes was beneficial in flushing out both the filters and the outlet stream. The relative stability of the filter effluent was reduced to less than 20 per cent on the worst day.

FIGURE 1.—View of Imhoff tanks at Dallas, Texas showing spray jets used to facilitate skimming.

Skimming Aid

With twenty-four Imhoff tanks, each of 1 m.g.d. capacity, the task of scum removal at the sedimentation chambers of these units in the Dallas, Texas, sewage treatment plant takes 8 hours' attention each day. Such manual attendance would be much greater were it not for the water jet system illustrated in Figure 1. These sprays knock down some of the floating solids, reducing the amount of scum requiring removal, and gather the rest of the scum at the ends of the tanks so that skimming labor is minimized.

Some Imhoff tank operators will be envious of the excellent scum control in the gas vent shown at the right in Figure 1. The photograph is a part of the 1945 annual report on the Dallas plant, as prepared by Supt. L. C. Billings.

"Manual" Sludge Disposal

The distribution of sale copies of the Federation's Manual of Practice No. 2, "Utilization of Sewage Sludge as Fertilizer," has been fairly good, but the number of extra copies purchased by municipal sewage treatment departments has been quite low. This leads us to suggest that a small investment in a supply of copies of the manual might be turned to advantage in keeping sludge stock piles within bounds.

Where there is difficulty in getting local users to take sludge away from the plant property, it is suggested that the interest of some large users might be developed by giving them a copy of the manual to study and keep for reference. Such complimentary copies should be given particularly to farmers located adjacent to or near the plant and to greenskeepers at local golf courses. A few gift copies so distributed and supplemented with a bit of personal interpretation by the sewage works superintendent might well result in the creation of a steady local outlet for the entire sludge production of a plant of moderate size.

Please note that the special membership rate of 75 cents per copy will be extended on orders for the fertilizer manual placed by municipal purchasing departments, if the special rate is claimed through the membership of any employee of the municipality. The order should indicate the name of such employee-member if the special rate is claimed.

Binders for Manuals

With two of the Federation's Manuals of Sewage Works Practice already distributed and others in the production line, it has been suggested from many quarters that ring binders be made available so that the various manuals can be protected from wear and filed together for convenient reference. Upon authorization of the Board of Control, such binders are now in supply and orders placed at Federation headquarters can be filled immediately. They are priced at $2.00 each.

The new binders are of special size to fit the manuals and are equipped with end triggers for opening the 1-in. rings. They are covered with durable simulated black leather, stamped in gold on the front and back edge. Sturdy, convenient and practical, the binders will make an attractive addition to any bookshelf, and will keep the manuals together for quick and easy use.

Editorials

THE CONCURRENT SAN FRANCISCO MEETINGS

The concurrent 1947 annual meetings of the American Water Works Association and of the Federation, which will assuredly assemble the largest congregation of water and sewage works technicians in history, is certain to be a successful event. Undertaken with trepidation in some quarters (and we must admit to a slight personal doubt when the idea was broached), there need be no fear but that both of the participating organizations will gain by the experience.

One of the early arguments against the concurrent meetings was that the Federation would be overwhelmed by the larger water works group. This will positively not be the case, by virtue of the good offices of AWWA Secretary Harry E. Jordan, who has gone far beyond all reasonable expectations in respecting the interests of the Federation. It has truly been a pleasure to work with Harry Jordan in coordinating the arrangements for the meetings. Through all of the negotiations, the give-and-take aspects have been remarkable for their balance.

There are both advantages and disadvantages to the concurrent meetings plan, and it will be interesting to analyze individual reactions during and after the San Francisco trial. One thing is certain—the first attempt will be a good one—having the wholehearted support of the participating professional organizations and their allied manufacturers' association. It will be a sound test.

Among the advantages of the concurrent meetings are (1) the convenience and economy of time and expense to the members of both AWWA and FSWA who ordinarily attend both annual meetings; (2) the offering of more elaborate entertainment and manufacturers' exhibits than would be possible in separate meetings; and (3) the attraction of a much larger registration, increasing the opportunities for personal contacts.

On the other hand, it is the very magnitude of the concurrent meetings that gives rise to the chief disadvantages, which are (1) the limited choice of convention sites, because few cities have good facilities for such large meetings; (2) the inconvenience resulting from the scattering of events among various halls and hotels; and (3) the lack of fellowship, usually at its best in a small and compact group. Another disadvantage is the "three-ring circus" aspect of the concurrent programs, which may frequently put a registrant in the position of having to decide between two simultaneous sessions when he would like to attend both.

The major factors in bringing about the San Francisco concurrent meetings this year were that the AWWA and FSWA were both committed to meet on the Pacific Coast in 1947, and that an attempt to stage the two meetings separately and only three months apart might have invited failure. It is expressly understood in both organizations that the 1947 arrangement is not to be assumed as a precedent for future meetings.

It is the writer's opinion that the general interests of all members of the two associations will best be served under ordinary conditions by the holding of separate annual meetings. There may be other occasions, however, when it will be of mutual advantage to use a common setting, and it is believed that the 1947 "double feature" will stand as proof that it can be done successfully.

W. H. W.

S. C. MARTIN JOINS FEDERATION STAFF

For the past year or two it has been more and more apparent that the Federation headquarters staff was undermanned, and that expansion would be necessary in order to do justice to the varied administrative, editorial, publishing and service functions. This deficiency was rectified on July 1 when S. C. Martin, formerly Principal Sanitary Engineer in the sanitary engineering division of the Illinois Department of Public Health, assumed the position of Executive Assistant in the headquarters office.

A native of Ohio, Martin took his undergraduate work at the University of Akron and at Ohio State University, obtaining his degree in civil engineering at the latter institution in 1931. He went on at Ohio State to secure his M.S. in Sanitary Bacteriology in 1932. He then entered the graduate school at Iowa State College, taking additional work in sanitary engineering and chemistry, and completing all formal course work toward his doctorate.

Except for a 3½-year period of varied service in the Army Sanitary Corps during the war, Martin has been engaged since 1936 in the engineering division of the Illinois state health department. This experience has been in all phases of stream pollution control and sewage works activity. Prior to his acceptance of the Federation appointment, he was in charge of all sewage works operation supervision as conducted by the Illinois Sanitary Water Board. He is held in high regard by the plant operators of the state, and has a thorough understanding of operational problems.

As Executive Assistant, Martin will collaborate in all aspects of management and administration of the Federation. He will also have certain editorial duties in connection with the JOURNAL, one of which will be to develop further "The Operator's Corner." The writer has not been satisfied with this feature for some time and has been unable to devote to it the amount of time required to secure and prepare the desired material. Martin will also assume production of the abstract section in a few months.

The expansion of the headquarters staff is in anticipation of the production of the JOURNAL on a monthly schedule as soon as publishing conditions favor the move. In the meantime, it will be possible to give badly needed attention to certain fundamental details of business management which could not be dealt with adequately heretofore.

The Federation is fortunate in securing the services of a man of Martin's qualifications. It is now in better position than ever before to serve its members and to achieve its aims and objectives.

W. H. W.

Proceedings of Member Associations

ARKANSAS WATER AND SEWAGE CONFERENCE

Sixteenth Annual Meeting

Fayetteville, April 14–15, 1947

Held under the joint sponsorship of the University of Arkansas and the Arkansas State Board of Health, the 16th Annual Arkansas Water and Sewage Conference was held at Fayetteville on April 14–17, 1946. Registration for the meeting was 103, the second highest in the history of the Conference.

The conference was opened on Monday morning, April 14 with Chairman W. R. Spencer presiding, the first session being devoted to discussion of the state program for licensing of water works operators and of retirement programs for municipal employees. Chairman Spencer presented the first topic and the talks on retirement programs were given by G. H. Campbell and John Luce.

Lectures on "Breakpoint Chlorination," by O. S. Porter and on control tests in water treatment, by G. F. Bell, were given on Monday afternoon, followed by laboratory demonstrations. At the dinner on Monday evening an address entitled "The Current USPHS Drinking Water Standards" and a moving picture illustrating the hazards of cross connections and back siphonage were presented by State Sanitary Engineer F. L. McDonald.

The Tuesday morning program was devoted to a series of short talks on water distribution problems and was followed by the annual business meeting. The 1947–48 Conference officers elected were: *Chairman*—J. R. Pierce of Pine Bluff; *Vice-Chairman*—Neal B. Thayer of Jonesboro; *Secretary*—Dr. Harrison Hale of Fayetteville. These officers are ex-officio officers of the Sewage Works Section of the Conference, by which the Conference is represented in the FSWA. F. L. McDonald of Little Rock continues to represent the Sewage Works Section on the Federation Board of Control as Director, his current three-year term expiring in October, 1949. An Awards Committee including Marion L. Crist, F. L. McDonald, M. H. Phillips and N. B. Thayer was appointed to serve the Sewage Works Section.

A feature of the Tuesday afternoon program was a report by FSWA Vice-President George S. Russell on current activities of the Federation. Mr. Russell's remarks were followed by an open discussion of sewage collection and treatment problems which was led by Ben W. Dees with C. H. French, Dan Millinder, Harry H. Clayton, T. W. Clapham and Walter Wilson assisting.

Dr. Harrison Hale, Secretary of the Conference, presided at the annual dinner on Tuesday evening. An address "A Newspaper Editor Looks at his Town's Water Supply," by C. F. Byrns of Fayetteville, was the highlight of this event.

Wednesday, April 16 was devoted to licensing examinations for water works operators and to an inspection trip of the sewage treatment plant at Springdale, Ark. City Engineer Walter Wilson conducted the visitors through the plant, which is a new one including biofilters and multistage digestion.

KANSAS SEWAGE WORKS ASSOCIATION

Second Annual Meeting

Wichita, Kansas: March 13–14, 1947

The Second Annual Meeting of the Kansas Sewage Works Association was held jointly with that of the Kansas Section, AWWA at the Hotel Broadview in Wichita on March 13–14, 1947. These organizations have replaced the Kansas Water and Sewage Association, which was dissolved in 1946.

Following a short general business session, the joint meeting was greeted by AWWA President-elect N. T. Veatch and FSWA Vice-President George S. Russell. Both of the national officers described current activities, accomplishments and aims of their respective organizations.

The technical program gave major emphasis to water works problems, although the panel discussion on public relations and certain other papers were of general interest to both fields. Showing of the film "Clean Waters" (courtesy of the General Electric Co.) and a panel discussion on sewage works operation problems were the principal program features for sewage works technicians. Leaders in the panel discussion were Murray A. Wilson, consulting engineer, Salina; O. M. Goodrich, city manager, Stockton; E. L. Filby, consulting engineer, Kansas City, Mo.; Neal Harr, city engineer, McPherson; and G. S. Russell, consulting engineer, St. Louis, Mo.

The address "A Governor's Private Diary," by Payne Ratner, former governor of Kansas, was the highlight of the banquet program.

The annual business meeting was held Friday afternoon, March 14, with Chairman Murray A. Wilson presiding. Officers elected to serve the association for the year 1947–48 were: *Chairman*—Neal Harr of McPherson; *Vice-Chairman*—Ray E. Lundy of Goodland and *Secretary-Treasurer*—Ben L. Williamson, recently appointed State Sanitary Engineer, who will have his headquarters at Lawrence. Major C. Hagar, Secretary-Treasurer of the Kansas Section, AWWA, was appointed to serve the sewage works association in similar capacity until Mr. Williamson is able to assume his new duties. P. E. Kaler of Topeka will continue as director to the FSWA Board of Control, his 3-year term expiring in October, 1948.

A resolution was adopted unanimously in which the past services of former secretary-treasurer Paul D. Haney were acknowledged. Mr. Haney recently accepted a position as associate professor of sanitary engineering at the University of North Carolina, and assumed his new duties on March 15.

MAJOR C. HAGAR,
Acting Secretary-Treasurer

NEW JERSEY SEWAGE WORKS ASSOCIATION

32nd Annual Meeting

Trenton, N. J.; March 19–21, 1947

The 32nd Annual Meeting of the New Jersey Sewage Works Association was held in the Stacy-Trent Hotel, Trenton, N. J., on March 19–21, 1947. Total registration was 310.

The meeting was convened at 10 A.M. on Thursday by President L. J. Fontenelli, for a technical session including the following papers:

"Statutory Requirements and General Policies of the State Department

of Health Respecting the Correction and Control of Water Pollution in New Jersey," by H. P. Croft, chief engineer, and S. A. Kowalchik, principal assistant engineer, New Jersey State Department of Health.

"Abatement of Stream Pollution in New Jersey," by Prof. H. N. Lendall, head of Dept. of Civil Engineering, Rutgers University.

"The Case Against Federal Control of Stream Pollution," by Louis Auerbacher, Jr., counsel, Passaic Valley Sewerage Commission.

The afternoon session included only one scheduled paper—"The Sewer Authority Act," by Henry F. Russell, member of the firm of Hawkins, Delafield and Wood, New York City. The remainder of the session was devoted to discussion of the above papers. Leading parts were taken in the discussions by Walter R. Darby, director of the Local Government Division of the State Department of Taxation and Finance; Robert F. Darby, counsel to the Rahway Valley Joint Meeting; and F. V. Hugo, secretary of the Rutherford Joint Meeting.

The Friday program opened with the annual business meeting, at which a feature was the presentation of the Federation's Harrison Prescott Eddy Award for 1946 to Dr. H. Heukelekian, research specialist at Rutgers University. The award was made at this meeting by FSWA President F. S. Friel because of the inability of Dr. Heukelekian to attend the Toronto conference in 1946, at which the Federation awards for that year were announced. The association acted to retain all 1946 officers for another year of service, as follows: *President*—L. J. Fontenelli; *First Vice-President*—Leslie West; *Second Vice-President*—John Struss; *Secretary-Treasurer*—M. S. Kachorsky. P. N. Daniels and Henry Van Der Vliet were elected to the Executive Committee for 3-year terms. Mr. Daniels continues to represent the association as Director to the FSWA Board of Control, since his current term does not expire until October, 1948.

The Operators' Symposium following the business meeting on Friday was an outstanding success. The symposium was actually an open forum, patterned after the well-known "guided discussions" that have been featured by the Canadian Institute on Sewage and Sanitation for several years. Prepared lists of questions were distributed to stimulate the discussion, and opportunity was afforded for specific problems to be offered for comment and advice. Leslie E. West presided over the session, with assistance from H. C. Greenfield, Paul Molitor, Sol Seid and John Struss.

A new feature was the Manufacturers' Symposium on Friday afternoon, which concluded the meeting. Various manufacturers' representatives described the present situation on equipment and supplies, and answered questions by operators who have experienced recent difficulties in procurement of such items. The session found an excellent reception.

Entertainment events included a "Jam Session" on Wednesday evening, at which entertainment and refreshments were enjoyed. The "Annual Speechless Dinner" was held on Thursday evening, followed by a full evening of entertainment made possible by courtesy of the Water and Sewage Works Manufacturers' Association.

M. S. KACHORSKY,
Secretary-Treasurer

NEW YORK STATE SEWAGE WORKS ASSOCIATION

Nineteenth Annual Meeting
New York City, January 17, 1947

With registration at a pre-war level, the Nineteenth Annual Meeting of the New York State Sewage Works Association was held at the Hotel Henry Hudson, New York City, on January 17, 1947. The program of the one-day meeting was of high technical caliber, featuring industrial wastes topics.

The meeting opened with a business session, President Uhl T. Mann presiding. Officers elected to serve for the year 1947–48 were: *President*—A. G. Martin of Tonowanda; *Vice-President*—E. C. McKeeman of Freeport; *Secretary*—A. F. Dappert of Albany; *Treasurer and Assistant Secretary*—J. C. Brigham of Albany. Prof. Rolf Eliassen of New York City, E. A. Marshall of Geneva and Paul E. Bardet of New York City were elected to serve on the Executive Committee for 3-year terms.

The morning technical session included a paper "Tallmans Island Sewage Treatment Plant After Seven Years of Operation," by Supt. Henry M. Rath, and a paper "The Effect of Chromate Waste on the Activated Sludge Process," by Gail P. Edwards, Chief of Laboratories of the New York Department of Public Works. The latter contribution was discussed by F. E. Nussberger, chemist at the Tallmans Island plant.

The Annual Luncheon featured addresses by Francis S. Friel and George S. Russell, President and Vice-President, respectively, of the FSWA. Speaking on "The Growing Federation," Mr. Friel cited the physical growth of the Federation but emphasized the broadening scope of its activities and service. Mr. Russell presented details of the early planning for the concurrent meetings of the FSWA and AWWA in San Francisco in July, 1947.

The presentation and announcement of several annual awards also featured the luncheon. In token of his long and faithful service to the Association, Wellington Donaldson of New York City was announced as the NYSSWA nominee for the Federation's 1947 Kenneth Allen Award. The NYSSWA Kenneth Allen Memorial Award, recognizing outstanding research contributions, was made to Thos. M. Riddick of New York City and H. O. Johnson of Great Neck, N. Y., for their joint paper "Solids Removal as Influenced by Design" (THIS JOURNAL, **18**, 3, 419; May, 1946). The Lewis V. Carpenter Award, also given annually by the NYSSWA for an outstanding contribution in plant operation, was presented to Uhl T. Mann of Syracuse, N. Y., for his paper "Plain Aeration of Sewage" (THIS JOURNAL, **18**, 3, 459; May, 1946).

The afternoon technical program opened with the paper "Factors Influencing Self-Purification of Streams and Their Relation to Pollution Abatement," by Prof. C. J. Velz of Manhattan College, New York City. The paper "Problems in the Application of the B.O.D. Test in Pulp and Paper Wastes" was presented by Dr. Harry W. Gehm of New York City and was discussed by Roy F. Weston of the Atlantic Refining Co., Philadelphia, Pa. The session was concluded by the paper "Foam Phase and Conventional Biological Oxidation of Waste Sulfite Liquor," presented by R. P. Logan and H. Heukelekian, New Jersey Agricultural Experiment Station, New Brunswick, N. J.

On Saturday, January 18, following the regularly scheduled program, an inspection trip to the Tallmans Island sewage treatment plant was arranged. About 50 persons took this trip, which was conducted by Henry M. Rath, superintendent of the plant.

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Federation of Sewage Works Assns.	**Civic Auditorium, San Francisco, Calif.**	**July 21–24**
California Sewage Works Assn.	Civic Auditorium, San Francisco, Calif.	July 21–24
Pennsylvania Sewage Works Assn.	Electrical Engineering Bldg., State College, Pa.	Aug. 25–27
Georgia Sewage Works Assn.	Ga. Institute of Technology, Atlanta, Ga.	Sept. 17–19
Kentucky-Tennessee Industrial Wastes & Sewage Works Assn.	Brown Hotel, Louisville, Ky.	Sept. 22–24
North Dakota Water and Sewage Works Conf.	Dacatoh Hotel, Grand Forks, N. D.	September
Ohio Conference on Sewage Treatment	Deshler-Wallick Hotel, Columbus, Ohio	Oct. 2–3
Canadian Institute on Sewage and Sanitation	General Brock Hotel, Niagara Falls, Ont., Canada	Oct. 6–8
Iowa Sewage Works Assn.	Hotel Montrose, Cedar Rapids, Iowa	Oct. 9–10
Virginia Industrial Wastes and Sewage Works Association	Nansemond Hotel, Ocean View, Va.	Oct. 16–17
Missouri Water and Sewage Conf.	Jefferson City, Mo.	Oct. 27–28
North Carolina Sewage Works Assn.	Sedgefield Inn, Greensboro, N. C.	Nov. 10–12

Twentieth Annual Meeting

FEDERATION OF SEWAGE WORKS ASSOCIATIONS

Civic Auditorium

San Francisco—July 21–24

in conjunction with

CALIFORNIA SEWAGE WORKS ASSOCIATION

Federation Affairs

PROGRAM OF 20TH ANNUAL MEETING

San Francisco, Calif., July 21–24, 1947

Definitely a large scale operation, the Federation's 20th Annual Meeting at San Francisco in July will be an exciting departure from past conferences. Something new and different is in store for those who will attend.

Although two technical sessions and some social events will be held jointly, the Federation meeting will otherwise be held separately and concurrently with the 1947 Conference of the American Water Works Association. The anticipated combined registration of 2,200 to 2,500 will represent the largest gathering of water and/or sewage works technicians ever yet assembled. The California Sewage Works Association, host Member Association to the Federation on this occasion, will conduct its annual spring business meeting during the week.

The complexities of arrangements for this "triple feature" would have been overwhelming had it not been for the facilities available in San Francisco. The spacious Civic Auditorium there could not have been more perfectly planned, with its huge Arena for the joint manufacturers' exhibit flanked on both sides by meeting rooms large enough to accommodate 1,000 persons each. This, together with the facilities available for housing and social events in fifteen fine hotels, all contained in one of the nation's most interesting cities, will be the setting.

The Joint Local Arrangements Committee, headed by Co-chairmen Blair I. Burnson for the Federation and R. C. Kennedy for AWWA, has functioned expeditiously through its several subcommittees to prepare for the concurrent meetings. It has been a big job and all details, large and small, have been given attention.

THE PROGRAM

Monday, July 21

Morning and Afternoon

10:00 **Registration Opens**—Front Corridor, Civic Auditorium

Inspection of Exhibits—Arena, Civic Auditorium

Evening

9:00 **JOINT PRESIDENTS' RECEPTION AND DANCE**—Colonial Room, St. Francis Hotel

Tuesday, July 22

Morning

9:30 **Twentieth Annual Meeting Called to Order** by President Francis S. Friel—Polk Hall, Civic Auditorium

General Business Session

10:15 **Developments in Sewage Disposal for San Francisco**
Clyde C. Kennedy, Consulting Engineer, San Francisco, Calif.

Discussion
Ralph G. Wadsworth, City Engineer, San Francisco, Calif.

11:00 **The Portland Sewage Works Project**
H. Loren Thompson and J. C. Stevens, Stevens and Koon, Consulting Engineers, Portland, Ore.

Discussion
A. M. Rawn, Chief Engineer and General Manager, Los Angeles County Sanitation Districts, Los Angeles, Calif.

Afternoon

Ground Water Pollution Problems—Larkin Hall, Civic Auditorium; Joint Session with AWWA; Presiding—Wendell R. LaDue, President, AWWA

2:00 **Basic Concepts in Ground Water Law**
A. P. Black, Professor of Chemistry, University of Florida, Gainesville, Fla.

2:45 **Ground Water Production Works**
Malcolm Pirnie and R. Sawyer, Malcolm Pirnie Engineers, New York, N. Y.

3:20 **Formulating Legislation to Protect Ground Water from Pollution**
B. E. Doll, Deputy City Engineer, Huntington Park, Calif.

4:00 **Developing Standards for Protection of Ground Water from Pollution**
R. F. Goudey, Sanitary Engineer, Dept. of Water and Power, Los Angeles, Calif.

Discussion (Doll and Goudey papers)
Frank Stead, California State Director of Environmental Sanitation, Berkeley, Calif.

Evening

8:30 **JOINT GALA ENTERTAINMENT**—Arena, Civic Auditorium

Wednesday, July 23

Morning

Technical Session—Polk Hall, Civic Auditorium; Presiding—George S. Russell, Vice-President, FSWA

9:30 **Natural Purification Characteristics of a Shallow Turbulent Stream**
F. W. Kittrell, Acting Chief, Stream Sanitation Staff, Health and Safety Dept., Tennessee Valley Authority, Knoxville, Tenn.

Discussion
George E. Symons, Associate Editor, *Water and Sewage Works*, New York, N. Y.

10:15 **Effects of Sewage and Waste Disposal Practices on Industrial Operating Costs**

William J. O'Connell, Jr., Technical Consultants Ltd., San Francisco, Calif.

Discussion

Herbert C. Davis, President, Terminal Island Seafoods Ltd., San Francisco, Calif.

11:00 **Treatment and Disposal of Cannery Wastes**

L. F. Warrick, State Sanitary Engineer, Bureau of Sanitary Engineering, Madison, Wis.

Discussion

C. W. Klassen, Technical Secretary, Illinois State Sanitary Water Board, Springfield, Ill.

11:45 **Report of Activities of Industrial Wastes Committee, California Sewage Works Association**

W. T. Knowlton, Consulting Sanitary Engineer, Los Angeles, Calif.

Afternoon

Reclamation of Sewage Effluents—Polk Hall, Civic Auditorium; Joint Session with AWWA; Presiding—Francis S. Friel, President, FSWA

2:00 **Industrial Uses for Reclaimed Sewage Effluents**

N. T. Veatch, Black and Veatch, Kansas City, Mo.

Discussion

Earnest Boyce, Professor of Municipal and Sanitary Engineering, University of Michigan, Ann Arbor, Mich.

2:45 **Use of Reclaimed Sewage Effluents at Baltimore**

Abel Wolman, Professor of Sanitary Engineering, The Johns Hopkins University, Baltimore, Md.

Discussion

Ray F. Goudey, Principal Sanitary Engineer, Department of Water and Power, Los Angeles, Calif.

3:30 **Agricultural Uses of Reclaimed Sewage Effluents**

L. V. Wilcox, Agronomist, Rubidoux Laboratory, U. S. Dept. of Agriculture, Riverside, Calif.

Discussion

Dario Travaini, Superintendent of Sewage Treatment, Engineering Department, Phoenix, Ariz.

4:15 **Limits of Pollution of Water for Industrial Use**

S. T. Powell, Consulting Chemical Engineer, Baltimore, Md.

Evening

7:00 **ANNUAL FEDERATION DINNER**—Colonial Room, St. Francis Hotel

Thursday, July 24

Morning

9:00 **1947 Operators' Forum**—Polk Hall, Civic Auditorium; Presiding—Frederick G. Nelson, Manager Pacific Division, The Dorr Company, Inc., Los Angeles, Calif.

Experiences of an Old Time Sewage Works Operator
D. R. Kennedy, City Engineer, Long Beach, Calif.

Discussion
Ewald M. Lemcke, Maintenance Engineer, Orange County Joint Outfall Sewer, Anaheim, Calif.

Maintenance of Sewage Collection Systems
Don C. Davis, City Engineer, Turlock, Calif.

Discussion
A. Segel, City Engineer, Fresno, Calif.

Effects of Fruit Cannery Wastes on Sewage Treatment Plants
F. Wayland Jones, Superintendent of Sewage Treatment, Stockton, Calif.

Discussion
Eric V. Quartly, Superintendent of Sewage Treatment, San Diego, Calif.

Salaries of Sewage Works Personnel
Rueben F. Brown, Superintendent of Sewer Maintenance Division, Los Angeles, Calif.

Discussion
Morris M. Cohn, Editor, *Sewage Works Engineering,* New York, N. Y.

Afternoon

12:15 **Business Luncheon, California Sewage Works Association**—Whitcomb Hotel

1:30 **Biochemical Oxygen Demand Symposium**—Polk Hall, Civic Auditorium; Presiding—Charles Gilman Hyde, Consulting Hydraulic and Sanitary Engineer, Berkeley, Calif.

Effect of Temperature on Rate and Ultimate Biochemical Oxygen Demand
Harold B. Gotaas, Professor of Sanitary Engineering, University of California, Berkeley, Calif.

Monometric Measurement of B.O.D. of Domestic and Industrial Sewages
W. F. Langelier and David H. Caldwell, respectively, Professor of Sanitary Engineering, University of California, Berkeley, Calif. and Partner, Broom and Caldwell, Civil and Chemical Engineers, San Francisco, Calif.

Biochemical Oxygen Demand of Sulfite Waste Liquor
R. G. Tyler, Professor of Sanitary Engineering, University of Washington, Seattle, Wash.

3:30 **Adjournment of Twentieth Annual Meeting**

MANUFACTURERS' EXHIBIT

Original planning by Secretary Arthur T. Clark of the Water and Sewage Works Manufacturers Association allowed for 130 booths to comprise the manufacturers' exhibit in the Arena of the Civic Auditorium. The first call for reservations resulted in immediate allocation of this space. By using the corridors adjacent to the Arena, space was then made available for 32 additional booths, all of which are expected to be assigned. More than 100 companies will participate in the exhibit.

By far the most comprehensive showing of water and sewage works equipment ever to be staged, the exhibit will be a highly worthwhile feature of the San Francisco meetings. The program has been arranged to permit adequate time for inspection.

SOCIAL EVENTS

The Joint Presidents' Reception and Dance on Monday evening, July 21, is expected to provide the "get-together get-acquainted" purpose of an opening social function. Dress will be optional.

On Tuesday evening the Joint Gala entertainment will be staged in the Arena of the Civic Auditorium. Spectators will be seated in the balcony overlooking the manufacturers' exhibit, giving them an excellent view of the stage. The Arena is equipped with one of the largest pipe organs in the nation, and this will be used to supplement the entertainment. A diversified program including the best available talent will make this event a highlight of the week.

As has been customary, the Annual Federation Dinner on Wednesday evening will feature the presentation of the various honors and awards for the year. Provision is being made for modest entertainment.

LADIES' ENTERTAINMENT

Ladies' registration for the concurrent meetings is expected to exceed 500. The Ladies' Entertainment Committee, of which Mrs. Nelson Eckart is chairman, has arranged a series of special events that will supplement the evening functions to give the ladies a thoroughly enjoyable week.

The Presidents' Reception and Dance on Monday evening will be the opening event, with that day being left open for registration, shopping, etc. On Tuesday afternoon there will be a tea and Chinese fashion show in the Colonial Room of the St. Francis Hotel, followed in the evening by the Gala Entertainment at the Auditorium.

A tour of San Francisco will give the ladies an interesting afternoon on Wednesday. The trip will include all major points of interest, and will be made by chartered bus. The evening event on Wednesday will be the Annual Federation Dinner.

Thursday afternoon will offer a luncheon and bridge party at the beautiful Tonga Room of the Fairmount Hotel. A special program of Hawaiian entertainment will be featured here. This event will conclude the general ladies' program, except for the Annual AWWA Dinner scheduled for Thursday evening.

Headquarters for the ladies during the meetings will be the Borgia Room at the St. Francis Hotel.

REGISTRATION AND TICKETS

A registration fee of $3.00 each for men and ladies has been established both by the Federation and AWWA. The men's registration will include technical

session privileges, the Monday reception and dance and the Tuesday Gala Entertainment. Ladies' registration covers admission to the Monday reception and dance, the Tuesday entertainment, and the Wednesday afternoon tour.

Tickets for the FSWA and AWWA dinners on Wednesday and Thursday, respectively, will be priced at $5.00. Extra tickets for the Monday reception and dance will be available at $1.50.

Ladies' event ticket prices will be $1.50 for the tea and fashion show on Tuesday and $2.00 for the bridge-luncheon on Thursday.

Sale of separate special event tickets will be restricted to those who have registered for the meeting.

Tickets for the Business Luncheon of the California Sewage Works Association will be priced at $2.00.

SANITARY ENGINEERS FORM INTER-AMERICAN ASSOCIATION

As a result of two Inter-American Regional Sanitary Engineering conferences held in 1946 at Rio de Janeiro, Brazil and Caracas, Venezuela, a new association of sanitary engineering has been formed. More than 400 sanitary engineers, public health and public works administrators, chemical and civil engineers, sanitarians and sanitary chemists from the 21 American Republics gathered at these two meetings sponsored jointly by the Ministries of Public Health and Public Works of Brazil and Venezuela, the Pan American Sanitary Bureau, and the Institute of Inter-American Affairs.

This association, called "The Inter-American Association of Sanitary Engineering," is established exclusively for scientific and professional purposes and is a non-profit society. The principal objective is to reach, by common agreement, the solution of problems relating to sanitation and the establishment of standards for the uniform and continuous protection of the people of the hemisphere.

The association will publish a quarterly journal containing the technical papers presented at the conferences as well as news items and other articles of interest to persons interested in sanitary engineering.

Sanitary engineers and others engaged in allied sanitation activities are invited to become charter members of the association before the next conference to be held in one of the countries south of the Equator in November, 1947. Chile has been suggested as the location for this first regular conference of the association.

Membership in the association offers an opportunity to participate in the development of lasting understanding between the Americas through the common problem of protecting the health of the people by an exchange of ideas and by the association with individuals having problems and objectives similar to those in the U. S. Charter membership is now available to those interested by payment of annual dues of $3. Information may be obtained from Homer J. Hayward, U. S. Representative of the Membership Committee, Inter-American Association of Sanitary Engineering, N.W. Corner 17th and Constitution Avenues, Washington, D. C.

Reviews and Abstracts

Edited by

H. GLADYS SWOPE *

Allegheny County Sanitary Authority,
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The Problem of Digestion of Sludge at Sewage Treatment Plants Operated by the Federal Water and Sewage Service (Rio de Janeiro, Brazil). BY ELZA PINHO OSBORNE. *Boletim do Servico Federal De Aguas e Esgotos.* Rio de Janeiro, Brazil. No. 9, 17–26 (1944).

The Federal Water and Sewage Service maintains two sewage treatment plants—Penha and Urca (both sections of Rio de Janeiro). Penha, with capacity for 3.168 m.g.d.; 40,000 pop.; is part of a project for ultimate pop. of one million. Urca, for 11,000 pop., designed for 0.574 m.g.d., is actually receiving sewage from 1,000 houses with flow of 0.5 m.g.d. The Urca section comprises high class residences, casinos, clubs, etc.

Penha handles sewage from the working class section and from small homes. Penha is the most modern sewage plant in Latin America, comprising mechanically cleaned bar screens, detriting, Kennison nozzle with Builders recorder; primary and secondary Dorr clarifiers; Dorreo mixer and flocculator, Dorr multidigestion and sludge pumps. The digester gas is used in a Worthington 4 cylinder gas engine (57 h.p.) and the excess gas is burned. The plant has complete laboratory facilities and is arranged for operation as a chemical precipitation plant for plain sedimentation; for series sedimentation; etc.

The Urca plant is simply an OMS tank, a two-story tank, similar to the Imhoff with submerged scum section to keep the scum under pressure. Analyses of fresh sludge from the primary tank at Penha and OMS at Urca are tabulated below.

Plant	Moisture %	Solids %	Free Ammonia	pH	Organic Nitrogen	Volatile Matter	Ash
Penha	95.10	4.90	0.30	7.2	0.214%	68.7%	31.3%
Urca	98.99	1.01	0.21	7.0	0.043%	66.6%	33.4%

The volatile material and ash are calculated in relation to total solids according to APHA standards. The sludge solids, volatile and pH are compared with Table 54 in Keefer's "Sewage Treatment Works." (McGraw-Hill Publishing Co.). Factors influencing digestion are given as: Penha agitation in primary multidigestion employed on advice of various authorities shortened digestion time and augmented gas production. Time of digestion varied according to treatment adopted. Temperature is a factor of great importance. Control of reaction reduced digestion time. Penha digestion time between 30 and 40 days; Urca—80 to 90 days. After digestion sludge put on open drying beds and when completely dry used as humus on plants and gardens. Dry sludge characteristics were:

* It will be appreciated if Miss Swope is furnished all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in THIS JOURNAL. Publications of public health departments, stream pollution control agencies, research organizations and educational institutions are particularly desired.

Plant	Moisture %	Volatile Matter %	Ash %	Organic Nitrogen %
Penha	5.2	47.0	53.0	3.02
Urca	6.6	54.0	46.0	2.1

Volatile, ash and organic nitrogen are given on the dry solids basis. Dried sludge used for plants was: Penha—1,400 cu. ft. per week (5 times the amount expected). Urca—350 cu. ft. per week. All dried sludge placed on gardens in Vietoria (section of Rio) maintained by Brazilian Assistance League and visited regularly by a committee, including Mr. Keller (North American food specialist) to study efficiency of sludge as fertilizer. These studies convinced the committee that either sludge would materially increase crops of grass and other growths.

E. B. BESSELIEVRE

Operation of the Sewage Treatment Plants Controlled by the Analytical and Treatment Laboratory of Water and Sewage (Rio de Janeiro, Brazil.) BY BISMARCK DOS SANTOS PEREIRA. *Boletim do Servico Federal De Aguas e Esgotos.* Rio de Janeiro, Brazil. No. 9, 45–51 (1944).

Part 1. Operation of Penha Sewage Treatment Plant. The program of sampling and tests developed by the Central Laboratory were: (1) Collect hourly samples of sewage during pumping; (2) Take temperature and pH of each sample; (3) Note air temperature and climatic conditions; (4) Put samples in refrigerator, and run total and suspended solids; (5) Daily data on volume and weight screenings and relation in pounds per gal. to daily flow; (6) Calculate daily cost of operation; (7) Determine 5-day B.O.D. on raw after bar screenings; (8) Collect sample screenings; (9) Measure grit in Detritor; (10) Calculate organic matter in grit; (11) Check orientation of Detritor deflectors; (12) Prepare daily chart of volume of discharge expressed in thousands of liters (3.785 liters = 1 gal.) with data from recording meter; (13) Collect effluent samples every 2 hrs. and determine solids, suspended solids, and pH; (14) Calculate removal of suspended solids at primary clarifier; (15) Measure scum on primary clarifier; (16) Collect sample raw primary sludge once daily during pumping and determine—density, moisture, organic matter, pH and volume (with Imhoff cone); (17) Verify what quantity of primary sludge added to primary effluent will produce optimum flocculation; (18) With preceding data regulate dosage of coagulants; (19) Experiment with laboratory flocculator to determine best speed to produce best flocculation in plant unit; (20) Regulate plant flocculator according to 19; (21) Every 4 hours collect samples of effluent from secondary clarifier and determine—suspended solids, and pH; (22) Calculate the efficiency of the secondary clarifier based on effluent compared to raw; (23) Collect, once daily, samples of secondary clarifier sludge during pumping and determine—same as 16; (24) Collect samples in primary digester 5 times daily and determine—pH and temperature (agitator to be operated before sampling) and pH to be maintained between 7.0 and 7.8 and optimum temperature 82.4° F. If pH is less than 7.0 operate mixer for 10 min. and add lime until balance is restored; (25) Collect samples from secondary digester 5 times daily and determine—pH, temperature, and density; (26) Collect samples of supernatant and determine B.O.D. and suspended solids; (27) Collect samples of digested sludge and determine per cent organic matter (good digestion indicated by black, ashy appearance, asphaltic or creosote odor, homogeneous aspect, pH between 7.0 and 7.2 and moisture 94 to 98 per cent); (28) Calculate efficiency of secondary digester by comparing proportion of organic matter in sludge from the two clarifiers with digested sludge sent to drying beds; (29) Compute volume of sludge discharged to drying beds per month; (30) On dried sludge determine—moisture and volatile solids; (31) On gas determine—composition, calorific value and volume.

As the Urca plant is simpler, consisting only of bar screens, hand cleaned, grit tank and two OMS tanks and sludge drying beds, less extensive records were kept. Composite table of data on basis of program above is given below:

Analytical Results—Penha and Urca (Rio de Janeiro, Brazil)

Item	Penha	Urca
Raw Sewage (from pumping stations at plant) per 24 hr. (m.g.d.)	1.188	0.5
Settleable Solids (Imhoff cone) (p.p.m.)	5.0	8.0
pH	6.8	7.0
Temperature, F.°:		
Winter	73.4	71.6
Summer	80.6	82.4
B.O.D., 5-day (p.p.m.)	250.0	350.0
Suspended Solids, Total (p.p.m.)	250.0	440.0
Suspended Solids, Volatile (p.p.m.)	240.0	280.0
Suspended Solids, Fixed (p.p.m.)	10.0	160.0
Screenings (lb./24 hr.)	22.0	—
Detritor (grit) (lb./24 hr.)	5.5	—
Moisture (per cent)	28.0	—
Volatile Matter (per cent)	6.0	—
Fixed Matter (per cent)	66.0	—
Flow Variation		
Maximum (period)	8 to 12 A.M.	—
Minimum (period)	12 to 6 A.M.	—
Primary Clarifier (effluent)		
Suspended Solids, Total (p.p.m.)	25.0	—
Suspended Solids, Organic (p.p.m.)	15.0	—
Suspended Solids, Fixed (p.p.m.)	10.0	—
pH	7.0	—
Sludge:		
Density	1.018	—
Moisture (per cent)	97.6	—
Organic Matter (dry basis) (per cent)	1.6	*
Mineral Matter (dry basis) (per cent)	0.8	—
pH	6.8	—
Flocculation (based on lab. experiments):		
Aluminum Sulfate (p.p.m.)	40.0	—
Lime (p.p.m.)	25.0	—
Secondary Clarifier (final effluent):		
B.O.D. (p.p.m.)	—	200.0
Suspended Solids, Total (p.p.m.)	20.0	80.0
Suspended Solids, Organic (p.p.m.)	10.0	60.0
Suspended Solids, Mineral (p.p.m.)	10.0	20.0
pH	7.0	7.0
Imhoff cone (p.p.m.)	0 to 0.1	0.5
Sludge:		
Density	1.02	—
Moisture (per cent)	97.4	—
Organic (per cent)	1.8	—
Mineral (per cent)	0.8	—
pH	7.1	—
Digesters:		
Primary:		
Temperature, F.°	71.6	—
pH	6.4	—
Secondary:		
Temperature (summer), F.°	71.6	—
pH	7.2	—
Density (sludge)	1.018	—
Supernatant Liquor:		
B.O.D. (p.p.m.)	350.0	—
Suspended Solids, Total (p.p.m.)	350.0	—
Suspended Solids, Organic (p.p.m.)	300.0	—
Suspended Solids, Mineral (p.p.m.)	50.0	—

Analytical Results—Penha and Urca (Rio de Janeiro, Brazil)—Continued

Item	Penha	Urca
Digested Sludge (as discharged from digesters):		
Moisture (per cent)	95.1	90.0
Organic Matter (per cent)	2.4	6.0
Mineral Matter (per cent)	2.5	4.0
Density	1.016	—
pH	7.2	7.4
Sludge, Dried, from beds:		
Organic Material (per cent)	49.90	58.50
Mineral Material (per cent)	50.10	41.50
Gas, composition:		
Methane, CH_4 (per cent)	70.0	—
Carbon Dioxide, CO_2 (per cent)	27.0	—
Hydrogen (per cent)	3.0	—
Oxygen (per cent)	0.0	—

From observations during 1943, following averages were obtained for June.

Item	Penha	Urca
Discharge (flow) per 24 hours (m.g.d.)	1.267	0.5
Reduction B.O.D. (per cent):	60.0	43.0
Suspended Solids (per cent)	91.0	80.0
Settleable Solids (Imhoff cone) (per cent)	98.0	93.0
Temperature of Sludge Digester, F.°	64.4	—
Turbidity of Raw Sewage (p.p.m.)	100.0	—
of Final Effluent (p.p.m.)	50.0	—
pH of Final Effluent	6.8	—
of Digested Sludge	7.1	—
Alkalinity (raw sewage) (M.O.) (p.p.m.)	140.0	—
Raw Sewage:		
Chlorides (p.p.m.)	120.0	—
Nitrites (p.p.m.)	0.016	—
Nitrates (p.p.m.)	0.08	—
Free Ammonia (p.p.m.)	5.0	—
Screenings:		
Pounds per 24 hours	22.0	—
Temperature, F.°:		
Air	77.0	—
Sewage	75.2	—

E. B. Besselievre

Sewage Treatment as Seen by an Architect. By Nicholas M. Cirno. *California Sewage Works Association Journal,* XVII, No. 1, 14–19 (1945).

The architectural viewpoint of the proposed activated sludge plant at Hyperion for the City of Los Angeles, California is reviewed. A tour was made of many middle western and eastern plants to obtain a broad background on the problem. A number were found to be well designed, landscaped and maintained. However, other plants were found to be well planned but through mismanagement and lack of maintenance were no longer a credit to the community.

The trip resulted in the conclusion that (1) a sewage treatment plant can be made architecturally attractive, provided the architect is employed from the inception of the project, (2) well planned and executed landscaping is essential to the appearance of the plant, and (3) maintenance of the

equipment, buildings, and grounds is of the greatest importance.

It is pointed out that the architect should first become thoroughly familiar with the function of the plant. He should study the complete bio-chemical process as well as the manual and mechanical operations involved. With such a background he will be in a position to cooperate intelligently with the engineers with whom he is to work.

Since the function of a sewage treatment plant is operational in character, it is imperative that the fundamental layout of the plant be given primary consideration over the appearance of the individual buildings. However, early collaboration between the architect and the engineers can result in a more harmonious grouping of the buildings as to mass and height. In the design of the Hyperion plant, the fundamental layout was restricted to the use of a long and relatively narrow site, all within an area owned by the City of Los Angeles. With the exception of the administration and laboratory building, the location of each building was determined by its function in the layout of the plant on an operational basis.

In a plant of this size, the location of access roads becomes very important, as they must serve trucking operations and parking facilities for employees and visitors. Lanscaping of the roads and long frontage required considerable planning, as a proposed traffic artery extension and shoreline development are only 300 ft. from the nearest plant buildings.

It was concluded that with proper planning, use of materials, landscaping, and last but probably the most important of all, maintenance, the Hyperion plant will be one of which the Los Angeles metropolitan area may well be proud.

ROBERT P. LOWE

Sewage Disposal in California, Glances in the Past—Glimpses in the Future. BY LEON B. REYNOLDS. *California Sewage Works Association Journal,* XVII, No. 1, 20–26 (1945).

A history of the first plants, types of treatment and methods of effluent disposal are covered in this paper. In addition, the development of sewage treatment and disposal is covered for several cities.

Sewage treatment in California at various times for municipal and district installations is given as follows:

Type of Treatment	(a) 1929	(b) 1937	(c) 1941
Comminutors		2	5
Fine Screens	11	11	7
Pre-aerators		4	2
Flocculators			3
Vacuators			
Clarifiers (Primary) and Settling Tanks	6	44	67
Clariflocculators			3
Digesters	11	49	73
Clarigesters			4
Septic Tanks	66	79	62
Imhoff Tanks	83	103	76
Sand Filters	2	27	2
Contact Filters	1	2	0
Trickling Filters	30	50	45
Biofilters			9
Chemical Precipitation		3	3
Activated Sludge	8	16	9
Claraetors			1
Chlorination	21	47	54
Communities	177	234	218

List (a) includes 150 municipal, 16 sanitary districts, 1 sanitation district.

List (b) includes 146 municipal, 27 sanitary districts, 1 sanitation district.

List (c) includes 157 municipal, 34 sanitary districts, 6 sanitation districts, 5 public utility districts, 11 sewer maintenance districts.

In 1941 there were also 112 non-municipal plants constructed by state, federal, and private agencies.

The following summary gives the methods of municipal and district disposal in California as of January 1, 1941:

Method	Untreated	Treated
Dilution:		
In Salt Water:		
Ocean	8	22
Bay	32	10
Tidal Slough	20	8
In Fresh Water:		
Perennial Stream	14	19
Intermittent Stream	2	38
Drain	3	18
Total	79	115
Irrigation:		
With Cropping	2	48
Without Cropping	6	64
Total	8	112

The former conditions and progress are reviewed for Stockton, San Francisco, the East Bay Cities, San Jose, and Los Angeles. In particular, mention is made of the reports made by consultants at different times.

It was concluded that sewage treatment and disposal in California during the last twenty years has been remarkable, but nevertheless, both large and small communities still need improved facilities that will cost many millions of dollars.

ROBERT P. LOWE

Predigestion of Industrial Wastes. By FREDERICK G. NELSON. *California Sewage Works Association Journal,* XVII, No. 1, 27–36 (1945).

While the majority of industrial wastes can be treated by conventional methods, often the cost is out of proportion to the value of the industry. Canneries, dehydrating plants and other seasonal industries are faced with the problem of disposing of high strength wastes for relatively short periods.

Predigestion of high strength industrial wastes offers one way of providing partial treatment at a relatively low cost. In this process, all of the liquid is passed directly to a digestion tank where it undergoes anaerobic digestion in a manner similar to conventional separate sludge digestion. The principal differences are: (1) the material discharged to the digester may be much lower in solids than sewage sludge, (2) the detention, or digestion time, is shorter, (3) often no attempt is made to separate the suspended solids from the supernatant liquor, but rather a homogeneous material is drawn from the tank.

The principal advantages of predigestion may be summarized as follows:

(1) Predigestion of the wastes, rather than digestion of the settleable solids only, has the advantage of reducing the dissolved and colloidal solids as well as the settleable solids. This is of considerable importance on certain wastes where the dissolved and colloidal solids constitute the major portion of the polluting material.

(2) Relatively high percentages of reduction of B.O.D. are obtainable at low initial and operating costs. Five-day B.O.D. reductions of from 60 per cent to 80 per cent are obtainable on certain wastes with detentions varying from about 4 to 10 days.

(3) Material that has undergone predigestion has its pH fairly well stabilized near the neutral point. Therefore, septic action will not result in subsequent treatment processes as often happens in highly putrescible waste when being treated by conventional methods.

Successful treatment has been accomplished for wastes from yeast, malt syrup, distillery and solvent production plants.

Detailed experiments on predigestion of corn cannery wastes were made during the 1944 season at Plainview, Minnesota. Tests were conducted both at mesophilic and thermophilic temperatures with the mesophilic temperature generally being held between 95° and 100° F., and the thermophilic, around 135° F. The work was on a pilot plant scale with the digesters consisting of steel drums 23 in. diam. by 34½ in. deep. They were installed in water baths heated with waste steam. Uniform temperatures were maintained by frequent checking of the sludge temperature and manually controlling the amount of steam going to the water baths. Both the thermophilic and mesophilic tanks were seeded with sludge from the digester at the city sewage treatment plant. Operation was on the "fill-and-draw" method, with a given amount of sludge withdrawn from the digesters once daily, and an equal amount of raw waste added to the tanks.

The pH was maintained well above 7.0 without the addition of chemicals for both 10 and 15 day digestion periods, but had a tendency to drop when the digestion was reduced to 5 days. Therefore, the pH of this waste can be stabilized through digestion periods that are greater than some point between 5 and 10 days.

It appears that a good supernatant liquor can be produced from corn cannery wastes. Contrary to expectations, the suspended solids lost their colloidal quality and settled rapidly. No attempt was made to determine the reason for this, but it is entirely possible that it was due to the waste having a low alkalinity after digestion. An average B.O.D. reduction of 87 per cent was obtained for the supernatant liquor as compared to 60 per cent to 65

per cent actual reduction attributed to digestion without sludge separation. All these results were obtained at mesophilic temperatures, as the experiments at thermophilic temperatures were not satisfactory.

ROBERT P. LOWE

Production of Formalin from Digester Gas. BY HAROLD WILSON. *The Surveyor,* **105**, No. 2816, 27–28 (Jan. 11, 1946).

Sludge gas consists of about 70 per cent methane (CH_4) with about 30 per cent carbon dioxide (CO_2). Methane can, in theory, be used as the starting point for the synthesis of a large number of organic compounds. The oxidation of methane to formaldehyde (formalin) may proceed according to the reaction:

$$\underset{\text{methane + oxygen}}{CH_4 + O_2} \rightarrow \underset{\text{formaldehyde + water}}{HCHO + H_2O}$$

There is a demand for formaldehyde in South Africa as a disinfecting agent for clothing and textile materials generally. Furthermore formaldehyde is an essential constituent for the manufacture of many plastics.

A study of the reaction involving the direct oxidation of methane to formaldehyde indicated that it was not practicable to produce formaldehyde by this method. Attention was therefore given to the possibility of producing methyl alcohol (CH_3OH) which may be readily converted to formaldehyde.

In 1943 a pilot plant was constructed for the production of methyl alcohol and from this formaldehyde. The process consisted of treatment of the sludge gas for the removal of sulfur compounds; addition of the correct amount of water vapor; passage of the purified and humidified gas over a granular nickel catalyst kept at 950° C, for its conversion to carbon monoxide and hydrogen; cleansing of cooled gases of organic impurities by activated carbon; compression of the gases to 2,500 lb. per sq. in.; passing the compressed gases over granular zinc chromite which results in their conversion to methyl alcohol as follows:

$$CO + 2H_2 \rightarrow CH_3OH$$

Final steps involve cooling and separation of methyl alcohol from residual gases, conversion of methyl alcohol to formaldehyde, and solution of the formaldehyde in water.

The principal difficulty in the operation of the process has been that of securing a tubular converter which will withstand the high temperature (950° C.) and the extremely corrosive effects of furnace gases and reacting gases and at the same time be a sufficiently good conductor of heat to transmit the very large amount of heat required for the conversion. Stainless steel has so far given the longest life in operation.

The design of the plant was based on the capacity of the input of the compressor which was 12 cu. ft. of free gas at atmospheric pressure per minute. Both high and low pressure stages of the process are now in operation.

It is hoped that the output of methyl alcohol will be more than two gallons per hour. This, on conversion, will give four gallons of formaldehyde solution per hour. The output of this pilot plant will satisfy the urgent needs for formaldehyde solution and the experience gained on this plant will enable a decision to be reached regarding the economics of a large scale plant.

PAUL D. HANEY

Some Foibles of Sanitary Engineering. BY L. B. ESCRITT. *The Surveyor,* **105**, No. 2818, 63–64 (Jan. 25, 1946).

The most noticeable defects in sanitary engineering design are those due to a form of conservatism, the copying of previous designs without adequate thought, the use of recognized principles without complete understanding of their purpose, and a tendency to codify practice and to accept existing codes as binding.

Drainage

(*a*) *The gradients of sewers and drains.* Minimum gradients for drains and sewers were established empirically about 100 years ago as follows: 4 in.—1 in 40; 6 in.—1 in 60; 9 in.—1 in 90; etc. This rule was simple, easily remembered and universally applied. However, sewage engineers compelled by circumstances have used much flatter gradients with success and experience thus gained has shown that the mini-

mum satisfactory gradients for 6 in. and 9 in. sewers are certainly not steeper than 1 in 150 and 1 in 265, respectively.

(*b*) *Surface water drainage.* The subject of surface water drainage has been treated mathematically yet the primary assumptions still remain assumptions and have not been checked. For example in Britain it is usual to design surface water drains on the basis of the most intense storm likely to occur once a year. Why this particular storm was chosen is a matter of history and this policy does not conform to American practice where the storm not likely to occur more frequently than once in three years is used. Storm drain design is often based on scanty local records or upon a formula which, while close to the truth, is not an adequate substitute for a complete analysis of all data and application of known facts regarding the probable intensity of storms having various periods of recurrence.

Sewage Treatment

(*a*) *Detritus tanks.* It has been said that "there should be two or more detritus tanks, and the capacity of each should not be less than one-hundredth of the dry-weather flow." Experience has shown that this capacity is always unnecessarily and, in the case of smaller works, undesirably large.

(*b*) *Sedimentation tanks.* Another fixed rule has been that sedimentation tanks should have detention times of from 10 to 15 hours. American practice has proved that capacities of one or two hours' dry-weather flow can be satisfactory. There is now available sufficient evidence on which to base the principles of design of sedimentation tanks and a large increase in capacity does not produce a corresponding increase in the efficiency of sedimentation. Within limits the capacity may be adjusted to suit the convenience of the designer.

(*c*) *Percolating filters.* Sewages were given the classification of "weak," "medium" and "strong" and some designers of new works have, to be on the safe side, classified the sewage to be treated as "strong" without in any way adjusting the per capita flow value. This has resulted in overdesign.

Most filters are now being designed for a six foot media depth and there is a tendency to arbitrarily hold to this figure.

(*d*) *Humus tanks.* Humus (final settling) tanks often perform unsatisfactorily. The existence of the problem has not led to scientific investigation on how humus could be better retained. The only noticeable change in the design has been to increase capacity, the effect of which, theoretically, should be small. There does not appear to have been any attempt to design hopper bottomed tanks fitted with a decanting valve or to design two-story tanks similar to Imhoff tanks for preventing using sludge.

PAUL D. HANEY

Designing a Surface Water Sewerage Scheme. BY L. B. ESCRITT. *The Surveyor,* **105**, No. 2824, 179–181 (Mar. 8, 1946).

Discusses similarity of design of surface water (stormwater) sewers and sanitary sewers and methods of layout. The article intends to set out as simply as possible accepted (British) principles of design and means of application. The run-off from developed areas is proportional to the impermeability of the surface. The impervious area is determined by taking the gross area and multiplying by an impermeability factor. An example is as follows:

Roofs of houses	90,000 sq. ft. × 95%	85,500
Asphalted carriageways	150,000 × 90%	135,500
Footways, etc.	40,000 × 80%	32,000
Garden lands	750,000 × 10%	75,000
Total	1,030,000	327,500

Impermeability factor 327,500/1,030,000 = 0.318 (or 31.8% of total area) and impermeability factor × gross acreage = impervious area in acres. Table I gives the commonly used impermeability factors.

The only method for avoiding trial and error design is by the use of the Lloyd-Davies formula, $Q = 60.5 \times Ap \times R$ where 60.5 is a constant converting in. rainfall per hr. per acre to cu. ft. per minute. Q = run-off in cu. ft. per minute. Ap = area drained in acres × impermeability factor. R = intensity of rainfall in in./hr. Lloyd-Davies established the theory that the storm (the duration of which equals the time of concentration) causes the greatest runoff from an area. Table II

TABLE I

Type of Surface	Percentage Impermeability
Watertight roof surfaces	70 to 95
Asphalt pavements in good order	85 to 90
Stone, brick and wood block pavement with tightly cemented joints	75 to 85
Same with open or uncemented joints	50 to 70
Inferior block pavements with open joints	40 to 50
Macadam roadways	25 to 60
Gravel roadways and walks	15 to 30
Parks, gardens, lawns, meadows, depending on surface slope and character of sub-soil	5 to 25
Wooded areas depending as before	1 to 20

suggested for computing the intensity of storms and is the mean of the chart of Bilham's curve and D.S.I.R. curve.

Method of using Lloyd-Davies formula. Assume that the top end of the drainage system contains 5 acres of land. Then $Ap = 5 \times 0.318 = 1.59$ acres. R must be assumed to obtain the size of sewer. Suppose the length of the sewer is 1,200 ft. with a possible gradient of 1 in 200. Assume $R = 1$ in. rain; then $Q = 60.5 \times Ap \times R = 60.5 \times 1.59 \times 1 = 96$ cu. ft./min. which can be handled in a 12 in. pipe which gives 164 c.f.m. at $v = 209$ ft./min. Time of flow through 1,200 ft. pipe = 6 min. Add to this time of entry, to allow rain water to flow from roofs, through gutters, drains and over land, say 9 min. = total time of concentration, and by Table II appropriate rate of rainfall is 1.5 in. per hour. Using this rate the runoff is $60.5 \times 1.59 \times 1.5 = 144$ cu. ft./min. and 12 in. pipe will handle this area. Each additional area must be calculated in turn. Calculation should be prepared as per example.

TABLE II

Duration of Storm in Minutes	Intensity in Inches per Hour	Duration of Storm in Minutes	Intensity in Inches per Hour
5	2.16	32	0.68
5.5	2.05	33	0.67
6	1.95	34	0.65
6.5	1.85	35	0.64
7	1.76	36	0.63
7.5	1.69	37	0.62
8	1.62	38	0.61
8.5	1.56	39	0.60
9	1.50	40	0.59
9.5	1.46	42	0.57
10	1.41	44	0.56
11	1.33	46	0.54
12	1.26	48	0.53
13	1.20	50	0.52
14	1.14	52	0.50
15	1.09	54	0.49
16	1.05	56	0.48
17	1.01	58	0.47
18	0.98	60	0.46
19	0.94	62	0.45
20	0.91	64	0.44
21	0.88	66	0.43
22	0.86	70	0.42
23	0.83	75	0.40
24	0.81	80	0.38
25	0.79	85	0.37
26	0.77	90	0.35
27	0.76	95	0.34
28	0.74	100	0.33
29	0.72	105	0.32
30	0.71	110	0.31
31	0.69	120	0.295

TABLE III

Drainage Area	Gross Area Acres	Impermeability %	Impervious Area Acres
V	1.5	33.3	0.5
W	1.5	33.3	0.5
X	2.0	40.0	0.8
Y	1.2	33.3	0.4
Z	1.2	25.0	0.3

TABLE IV.—Lengths and Gradients of Sewers

Location	Gradient 1 in.	Length Feet
A_4–A_3	250	310
A_3–A_2	300	340
B_2–B_1	175	360
B_1–A_2	180	360
A_2–A_1	245	330
A_1–outfall	250	150

Table V shows complete calculation for an area using designations as in Table III and factors in Tables I and II and the Lloyd-Davies formula for each area.

The above gives the Lloyd-Davies method without refinements. It can be applied to small drainage areas. Adjustments must be made in calculations for large areas in time of concentration.

TABLE V

1 Location (Manhole to Manhole)	2 Drainage Areas	3 Impervious Areas (Ap) Acres	4 Time of Concentration (t) (Min.)	5 Rainfall Intensity (R) (Inches per Hr.)	6 Run-off (c.f.m.)
A_4–A_3	V	0.5	5(*3+2)	2.16	65
A_3–A_2	V+W	1.0	7(5+2)	1.76	106
B_2–B_1	Z	0.3	$5\frac{1}{2}$(*3+2.3)	2.05	39
B_1–A_2	Z+Y	0.7	$7\frac{1}{2}(5\frac{1}{2}+2)$	1.69	72
A_2–A_1	V+W+X+Y+Z	2.5	$9(7\frac{1}{2}+1\frac{1}{2})$	1.50	226
A_1–outfall	V+W+X+Y+Z	2.5	9	1.50	226

7 Diam. of Sewer (In.)	8 Gradient (1 in —)	9 Discharge (c.f.m.)	10 Velocity (Ft./Min.)	11 Length between Manholes (Ft.)	12 Time of Flow Through Length (Min.)
9	250	68.1	154	310	2.0
12	300	134	170	340	2.0
7	175	41.6	156	360	2.3
9	180	80.3	182	360	2.0
15	245	269	219	330	1.5
15	250	266	217	150	0.7

* = 3 minutes time of entry.

E. B. BESSELIEVRE

Diagram for Surface Water Sewer Calculations. By L. B. ESCRITT. *The Surveyor,* **105**, 229–230 (March 22, 1946).

The diagram provides a method of storm sewer design on an entirely graphical basis. Starting with the impervious area in acres and the time of concentration in minutes, the maximum flow may be read or used without reading to determine the suitable sewer size for the correct gradient. Finally, the diagram gives the velocity and the time of flow in the design sewer so that the time of concentration for the downstream line is quickly determined with sufficient accuracy. The diagram is based on recent statistical studies of rainfall rates rather than the Ministry of Health Standard Curve.

The diagram scales range as follows: Impervious area, 0.4 to 2,500 acres; time of concentration, 5 to 120 min.; maximum flow, 30 to 45,000 cu. ft. per min.; sewer size, 6 to 120 in.; gradient, 1 in 10 to 1 in 8,000; velocity, 2.5 to 9 ft. per sec.; and the time of flow in sewer, 1 to 19 min. in sewer lines 200 to 10,000 ft. long.

A similar time-saving diagram could be prepared for any locality.

RALPH E. FUHRMAN

Disposal of Sewage Sludge. By RONALD HICKS. *The Surveyor,* **105**, 303–306 (April 19, 1946).

The great improvements made in the processes of sedimentation and clarification have not been paralleled by similar improvements in sludge treatment. Even with the modern developments of separate sludge digestion and its gradual evolution from the early septic tank, serious problems prevail, particularly in sludge drying and disposal.

Modern methods of disposal are enumerated and briefly described. The disposal of sludge by dumping at sea as practiced at London, Glasgow, Manchester, Belfast, New York and other cities is attractive because of its economy, but is looked upon as a temporary expedient.

The disposal of liquid sludge on land is possible in some locations, but generally impossible. The method is attractive because of its logic where it can be used.

Open sludge drying beds are very common and are generally satisfactory where sufficient area is provided.

The lagooning of sludge is being practiced less because of the unavailability of the large land areas. Troubles are noted

with ground water pollution from this source.

Sludge pressing, while used in several plants, still presents difficulties which must be overcome for complete satisfaction. The use of heat treating of sludge has been reported with favor.

Covered sludge drying beds, while very popular in the United States and Canada, have not been constructed on any large scale in Great Britain. The difference in cost is responsible for this difference in application.

Mechanical dewatering of sludge has developed rapidly in recent years. Its application is to both raw and adjusted sludge with proper conditioning prior to filtration. The conditioning advantages are listed in the order of their efficiency as ferric chloride, chlorinated copperas, ferric sulfate, aluminum sulfate and chrome alum. The recent work at Manchester is cited indicating that the best results with activated sludge have been obtained by the use of ferric chloride without lime.

Savings in chemicals are possible by the use of sludge elutriation. The process is generally not attempted in the British Isles because of the high cost of ferric chloride. Another possible process for the conditioning of sewage sludge is by electrolytic means. An electrode of carbon is introduced into the parchment bag and another electrode of sheet iron is emersed in the running stream. When a direct current is applied the pH value of sludge falls very rapidly and the sludge becomes filterable without the addition of chemicals.

The sewage treatment works of Hamilton, Scotland, are briefly described. On a one foot square experimental filter, unwashed sludge from the secondary digester containing digested activated sludge gave a yield of 5.26 lb. of dry solids per sq. ft. of filter area per hour with 6.68 per cent ferric chloride. Washing of this sludge with four volumes of water gave a yield of 4.04 at a ferric chloride dose of 3.9 per cent.

The cost of handling Hamilton sludge by open beds, covered beds and vacuum filters has been extended with the lowest cost per year in favor of vacuum filters. The Hamilton plant is designed for an ultimate population of 50,000.

RALPH E. FUHRMAN

Sanitary Engineering and Public Health. BY DON E. BLOODGOOD. *Monthly Bulletin,* Indiana State Board of Health, 49, No. 5, 99 (May, 1946).

There are many ways in which engineering knowledge can be of assistance in improving and protecting the public health. Only within the last 50 years has the engineer been called upon to lend his assistance to the cause. The application of engineering principles to sanitation has resulted in the title "Sanitary Engineer." Today engineers are employed as consultants, by equipment manufacturers, and in federal, state and local health services.

Water treatment processes involves the application of engineering principles and the quality of the water delivered by the 13,000 municipal water supplies in the United States must be continuously safeguarded.

A properly designed sewage treatment plant serves as a block in the path of disease and the proper operation of such a plant definitely protects the public health. The 3,000 or more sewage treatment plants in the United States have been built to eliminate nuisances and to protect public water supplies. More plants are needed and their construction will be a benefit to public health.

Swimming pool water treatment makes use of equipment and processes similar to those used by municipal water treatment plants. Sanitary engineers have made important contributions to the design and operation of swimming pools.

Rodents, primarily rats, are definitely carriers of disease. Rat-proofing is not a simple task and the rat-proof construction of buildings requires the application of engineering knowledge.

Garbage collection and disposal is an important municipal service that must in the future be greatly improved through the development of more satisfactory equipment—an engineering problem.

Plumbing, heating, ventilation all effect the public health and all involve engineering problems.

Sanitary engineers have made important contributions to the safety of processing and packing of many foods.

Only through constant vigilance can the sanitary engineer assist in keeping disease under control and it is possible that disease

in its effort to survive may develop through evolution so that it may outwit those who provide measures for protection. Conditions which may result in the spread of epidemics yet unheard of must be anticipated and the paths of transmission broken. Cooperation between the sanitary engineer and other professions in the execution of public health protective measures is essential.

PAUL D. HANEY

Recent Developments in Retting of Flax and Disposal of the Waste Waters. BY T. W. BRANDON AND C. B. TAYLOR. *J. Soc. Chem. Ind* (Brit.), 204 (May 25, 1946).

Most of the new flax retting factories "were so situated that the waste liquor from anaerobic retting could not be discharged untreated without causing serious pollution. . . ." "The investigation therefore aimed at developing a new process of retting in which partial treatment of the liquor would enable it to be re-used in the process. Tests on both the semi-scale and on the full scale showed that if the liquor were aerated during retting it could be continuously re-used for retting successive batches of flax. At least 40 batches of flax could thus be satisfactorily retted with no discharge of waste waters, and the liquid remaining for disposal at the end of the series was only 2 or 3 times as polluting as the liquor from a single anaerobic ret."

H. GLADYS SWOPE

Vacuum Filtration at York Township. BY E. H. MUNROE. *Water and Sewage,* 84, 36 (September, 1946).

At the York Township plant it has been found that sludge delivered to the filters by the diaphragm pump is more easily coagulated than is sludge pumped by the stand-by centrifugal pump. The diaphragm pump can be adjusted to deliver sludge continuously at the rate best suited to filter operation and intermittent pumping can be avoided.

Two rotary filters are used at this plant. One is 10 ft. by 12 ft. and the smaller is 8 ft. by 8 ft. Filter screens made from solid rubber rope have given very good service. The screens are woven at the plant on a loom developed for the purpose. A cotton filter cloth is used. It has about 40 threads to the inch and gives a life of about 244 filter hours.

The filter cloth is secured to the drum by sash cord driven into slots in the marginal strips of the filter panels and at the extreme edges of the drum. Filter strings are used to lift the cake from the drum. The strings are spaced at 1½ in. intervals and they completely encircle the drum and discharge rollers.

Ferric chloride has been used as a coagulant for some years. Some tests have been made in an endeavor to reduce cost of sludge conditioning. The most promising results were obtained with ferric chloride in conjunction with diatomaceous earth. Savings of about 40 per cent were indicated.

During July trouble was experienced in obtaining ferric chloride and other coagulants were tried. Aluminum sulfate in a solution strength of 6 lb. per gal. gave highly localized coagulation, with many blind spots on the filter drum. Better results were obtained using 10 lb. per gal. plus 10 lb. of 20° Bé. muriatic acid per 100 lb. of aluminum sulfate.

T. L. HERRICK

Some Observations on the Operation of the Bishop Auckland Sewage Disposal Works. BY J. R. GRIEVE. *The Institute of Sewage Purification* * (February 22, 1947), 6 pp.

The author gives a description of the Bishop Auckland drainage district and the disposal works serving this district.

In the last mile of main outfall sewer, which is 30 in. cast iron pipe, grey fungus in large volumes forms, probably because of the availability of iron. It is broken down by sufficient chlorine. The manually cleaned grit channels remove about 3 tons of grit weekly. The bar screen which was installed instead of the rotary screen originally planned removes about two cu. yd. of screenings per week.

Detritus tanks provide two hours detention period at the dry weather flow. These tanks reduce the oxygen adsorbed by approximately 20 per cent. The storm over-

* A preprint.

flow chamber regulates the storm water flow so that it receives two-stage treatment, that is, double sedimentation and double screening. During the year, 6.2 per cent of the total flow passed through the storm tanks.

Sewage is metered by a standing wave flume 3 ft. wide. The sedimentation tanks consist of three circular tanks with a diameter of 50 ft. and saucer-shaped floors. The tanks operate in series and are fitted with mechanical sludge scrapers. The total detention period is approximately eight hours. The tanks have operated satisfactorily without scum boards.

There are sixteen percolating filters, all of the circular type. The media is 6 ft. deep and the dosage rate, 50 gal. per cu. yd. per day. The gravel filters operate with an efficiency of about 30 per cent on the basis of oxygen absorption and their operation is described as "unstable." During spring flushing periods the filters seem to clean themselves completely. The slag filters which operate under the same conditions give a purification efficiency of about 32 per cent. This efficiency is very constant throughout the year and no ponding is observed. The clinker filters have an efficiency of 33 to 35 per cent and operate very consistently but are subject to slight ponding in winter.

The four humus tanks operate in series and sludge is removed twice daily. The sludge is returned to the sewage inlet of the plant. The effluent is remarkably clear.

Sludge drying beds provide an area of 6,300 square yards which is equivalent to four persons per square yard. The dried sludge contains approximately 60 per cent moisture.

The area of the drainage district is 6,355 acres and its population is 35,611.

The following table shows the analyses for the year ending March 31, 1946:

Average Analyses for Year, Expressed in Parts per Million

	Crude Sewage	Tank Effluent	Final Effluent
Oxygen Absorbed (3 min.)	32.4	18.1	
Oxygen Absorbed (4 hr.)	99.1	39.5	5.1
B.O.D.			8.14
Chlorides	86.6	78.6	74.5
Alkalinity	244.9	202.0	83.4
Settleable Solids	87.3	nil	0.008

A flow chart of the disposal works is also included.

RALPH FUHRMAN

The Economic Flocculation of Sewage Colloids. BY J. FINCH AND S. L. WRIGHT. *Institute of Sewage Purification* * (February 22, 1947).

In a series of laboratory tests on the aeration of settled sewage and activated sludge, it was established that the initial rate of purification was very high. During the first hour, the colloids were removed rapidly as shown by the decrease in turbidity. When sufficient sludge was added to give a volume of 3–8 per cent after settling for an hour, about one-third of the oxygen consumed from permanganate was removed after 30 min. aeration. Without activated sludge, only 6–15 per cent of the oxygen consumed value was removed. Purification improved as the concentration of sludge increased. The return of the aeration tank effluent to the aeration unit resulted in better purification than the return of the same amount of concentrated solids. Reaeration or reactivation of the sludge after flocculation in a bio-flocculation plant does not seem economical.

An economic bio-flocculation plant would have a detention period of about thirty minutes and use activated sludge concentrations (based on settling for one hour) of 3–7 per cent. The sludge must be fresh, well aerated activated sludge.

G. P. EDWARDS

Fifth Annual Report of the Interstate Commission on the Potomac River Basin.* July 1, 1945–June 30. 1946, 23 pp.

The Potomac River is the second largest in the point of discharge on the Atlantic Coast and is one of the more important streams in the United States. In addition to the Nation's Capital, it serves many important industries and large recreational areas. The report is devoted to the prog-

* A preprint. Presented at the Leeds meeting.

* 502 Transportation Bldg., Washington 6, D. C.

ress in reducing the pollution of the Basin during the 1946 fiscal year.

The Commission obtains technical advice from two committees, the Technical Committee and the Industrial Committee. The Technical Committee is made up of the directors of state planning boards, the state sanitary engineers and similar federal representatives. The Industrial Committee is made up of men working in industries within the Basins. These Committees assist the Commission in its role as a regional planning and coordinating agency.

During the year the water quality criteria and zones of principal water use have been finally approved by the Commission. These criteria provide a measure of minimum standards for the streams in the Basin.

The Commission has interested itself in and has aided in the plans for the completion of the Savage River Dam. The completion of this dam will help greatly in the relief of water supply, stream pollution and flood control problems in the upper portion of the Basin.

The Commission has likewise promoted agreement between the District of Columbia and the Washington Suburban Sanitary District in adjacent Maryland. When put into effect this plan will take sewage originating in Maryland to the District of Columbia Sewage Treatment Plant for treatment prior to discharge into the Potomac River. The minimum water quality criteria adopted are as shown in the attached table.

Minimum Water Quality Criteria for Streams in the Potomac River Basin

	Class A Drinking Water (No treatment except Cl.)	Class B Bathing, Fish Life Recreation	Class C Domestic Water Supplies (before complete treatment) Industrial Process Water	Class D General Sanitary Condition—to prevent nuisance
Coliform bacteria MPN per 100 ml.	0 to 50	Monthly av. 50 to 500 Max. not over 1,000	Monthly av. 50 to 5,000	——
Color, p.p.m.	0–10	20 (desirable)	Amt. of color and turbidity allowed which can be removed by standard equipment and practices.	——
Turbidity, p.p.m.	0–10	40 (desirable)	——	——
pH	6.0 to 8.0	6.0 to 8.5	6.0 to 8.5	6.0 to 8.5
5 day B.O.D., p.p.m.	——	1.5	2.0	3.0
Monthly av., p.p.m.	——	3.0	4.0	5.0
Max. observa., p.p.m.				4.0
Dissolved oxygen, p.p.m.				
Monthly av., p.p.m.	7.5	6.5	6.5	Min. daily av. 3.0
Min. observa., p.p.m.	6.5	5.0	5.0	Absolute min. 2.0
Other conditions	No toxic substances, oils, tars, or free acid at any time. No floating solids or debris, except from natural sources. No taste- or odor-producing substances. No sludge deposits.	Same as A	Same as A	No toxic substances, oils, tars, or free acid at any time. No floating solids or debris, except from natural sources. Slight localized sludge deposits, if unpreventable, allowed. No offensive odors.

Note: These standards are to be used only in conjunction with a sanitary survey as a guide to determining the minimum water quality for the various classes of water use listed. It is intended that these criteria should apply to conditions which are expected to prevail for the major part of the time.

RALPH E. FUHRMAN

The Potomac River Valley. BY JAMES BIRCHFIELD. *The Evening Star,* November 17–26, 1946, 12 pp.

This series of newspaper articles was prepared to show what the Potomac River Basin pollution problem is and what steps are or should be contemplated to correct pollution problems. The Basin is referred to as a proving ground in coordination between the four states, the Federal Government and the Government of the District of Columbia. The need of sewage treatment plants is pointed out in

the upper Potomac Valley to rid that portion of the Basin of pollution. The upper reaches of the river laden with acid mine wastes receive heavy loads of industrial wastes and sewage pollution. In addition to treatment of sewage the increase of low water flow as will be given by the Savage River Dam will be beneficial. The other problems considered in the series of articles include preservation of certain streams where game fish abound, the pollution of the District of Columbia water supply by the mid-Basin area and the pollution of the lower Potomac by the National Capital area.

RALPH E. FUHRMAN

Refinery Waste Disposal—XIII. Storm Run-off in Open Sewers and Ditches Can Be Accurately Measured by Weirs. BY W. B. HART. *Petroleum Processing,* 2, 31–34 (January, 1947).

This article points out that storm run-off water can be measured easily where it is collected in ditches, or open sewers. Rectangular suppressed weirs, rectangular contracted weirs, and triangular weirs are described, formulas are given for calculation of flow, and values for the constant C are tabulated for the different types of weirs. The dimensions of Parshall flumes for throat widths from 0.5 to 5.0 feet are listed.

Where flows are to be measured by such devices it is important that the total flow pass through them, that the velocity of the waste as it approaches the device must be relatively low, and that the proper equation be used to compute the flow. If the dry weather flow from an area drained by a sewer system is measured and used as a datum, it is a simple matter to measure the rate of run-off during a storm. Rainfall is measured by a rain gage, and quantity is plotted against time for both storm and dry weather run-off; the difference will be the storm run-off. This value can be related to the rainfall rate and time to determine the extension of the run-off time beyond the cessation of the storm. Any treatment plant should be able to handle the flow from a storm of such high intensity that a similar storm could be expected to occur only once in ten years.

It may be necessary to *estimate* the rate at which storm run-off will flow to a particular point. This is an involved and difficult problem on which there is an extensive literature. There are no studies, however, of run-off rates from areas which are comparable to refinery properties. Where the run-off rate from a definite type of surface has been measured, these data can be modified to estimate run-off rates from other areas of similar character. The total volume of run-off is relatively unimportant; run-off rates form the basis for design of waste treatment plants.

Rainfall is dissipated in several ways, of which the most important are infiltration, evaporation, and run-off. Rain which seeps into the ground is fixed, and, though it may later appear as subsurface flow, it is important compared with surface run-off. Surface porosity is a most significant factor in estimating run-off rates. Porosity may range from that of a concrete pavement, where it is nil, to loose, sandy soil, where it is quite high. The rate of saturation of the surface receiving the rainfall is therefore a controlling factor in run-off rate. Evaporation usually plays a small part in most localities in reducing run-off rate, but surfaces which have been wetted dry off after a rain, and some vegetation may retain considerable water which later evaporates.

Most refineries have rather complete sewer systems, and the tendency is to provide sewer inlets at frequent intervals so wastes will be carried away promptly from any area. Thus refineries are divided into a series of areas, and a summation of the run-off rate from each will yield a run-off rate for the total area. But whether this method of estimating the total rate from a group of areas, or the unit hydrograph method favored by engineers, is adopted, the assumptions that must be made for each are such that the result may be greatly in error.

RICHARD D. HOAK

Refinery Waste Disposal—XIV. Disposal Needs Based on Graph Method for Finding Run-off to Rainfall Ratio. BY W. B. HART. *Petroleum Processing,* 2, 131–34 (February, 1947).

Graphs are presented as an aid in estimating run-off rates from a refinery in the design stage. Three types of surface are

discussed: fully paved, hardpacked roadways plus some soil of normal density, and tank farm areas.

Estimates made from the charts are applicable only up to the sewer inlets. Sewer rates should be estimated by using floats or dyes; these rates will act to extend the run-off time, with no increase in run-off volume. It is emphasized that these will only be estimates which may be in considerable error, because of the dearth of literature dealing with the estimation of run-off from industrial areas.

RICHARD D. HOAK

Refinery Waste Disposal—XV. Basic Natural Law—Not "Rule of Thumb" Should Apply in Sedimentation Methods. By W. B. HART. *Petroleum Processing,* **2**, 193–97 (March, 1947).

The permissible quantity of oil in waste waters intended for discharge into surface water has not been established definitely. Some years ago, 30 p.p.m. was accepted as satisfactory, but the tendency in some sections now is to demand as little as 5 to 10 p.p.m. Somewhat intricate treatment methods must be employed to meet these requirements.

For practical purposes, petroleum products are completely immiscible with water. This characteristic permits separation by sedimentation, but, in the past, separation devices usually were designed by "rule of thumb," and both natural laws and the empirical designs of the sanitary engineers were ignored.

There are a number of factors which govern the separation of oil from water by sedimentation under conditions which are applicable to refinery waste treatment. Stokes developed a law which states that the velocity with which a particle will settle (rise, in the case of oil) is directly proportional to the square of the particle radius and the difference in density between particle and suspending medium, and inversely proportional to the viscosity of the suspending fluid. Stokes worked with undeformable metallic spheres, however, and it is known that oil globules are deformable. Bond evaluated this effect mathematically and introduced a term in Stokes' equation to correct it for globule deformation. This term, which may have a value between 1.0 and $\frac{2}{3}$, depends on a relation between the viscosity of the suspending fluid and the viscosity of the oil in the globule. Each of the terms in the equation is discussed in detail by the author.

Stokes' Law applies only under conditions of quiescence. Translation from batch or quiescent settling to continuous operation is illustrated by an example. Assume that waste water containing oil is discharged into one of a series of tanks; when the first becomes full, the discharge is transferred to the second, and so on. While the other tanks are being filled the contents of the first tank settle under quiescent conditions, and all of the oil gradually accumulates on the surface of the water. While the last tank is being filled, the oil is removed from the first tank and the water drawn off to disposal. The cycle is then repeated. Now imagine that these tanks are rectangular, and are arranged in a row with a common wall dividing each from its neighbor. The process is still operated cyclically, under ideal conditions. Finally, imagine that the common walls are removed and that the oily waste continuously enters one end while oil-free water is discharged from the other. This would represent the simplest form of the gravity-type, oil-water separator.

The ideal conditions of quiescent sedimentation normally cannot be obtained in a continuous settling tank because of the necessity for certain accessories. The first important factor in the design of continuous sedimentation basins, is flow rate. Unless the flow is so controlled that it is free from turbulence or thermal currents, it will act as a mixer instead of a separator. In laminar, or straight-line flow, a point in any vertical transverse section has the same velocity as any other point in that section, or in another similar section; and there is no difference between batch and continuous sedimentation. As completely laminar flow cannot be obtained in practice it is important to minimize as much as possible the turbulence resulting from flow around accessories.

The factors important in producing laminar flow are the optimum cross-section of the channel, and the critical velocity of the fluid. The latter factor is directly proportional to the kinematic viscosity of

the fluid and the hydraulic radius of the channel. The author shows mathematically that the breadth of the channel should be twice its depth. He then assumes a channel 20 ft. wide and 10 ft. deep and calculates, from his formulae, that such a channel would have a capacity of only 55.8 g.p.m. for theoretically perfect sedimentation conditions.

It is pointed out that the fundamental conditions should be used as a basis for settling basin design, but the various values need not be strictly adhered to, because of the impossibility of obtaining laminar flow in practice.

This development will be continued in the next article.

RICHARD D. HOAK

Book Reviews

Standard Methods for the Examination of Water and Sewage. Ninth Edition, 1946. Published by American Public Health Association, 1790 Broadway, New York 19, N. Y. Price $4.00.

This book has been eagerly awaited by sanitary chemists for well over a year, not only because the Eighth Edition has been out of print, but because many new methods have been proposed.

The Ninth Edition is not all that could be hoped for and the work is best summed up in the words of Dr. John F. Norton, Chairman of the Joint Editorial Committee, in the Preface. "No manual of laboratory procedures for water and sewage examination is static, nor can it endure more than a few years; neither can it meet the requirements of all water analysts in all interrelated fields. It has been necessary to choose as 'standards' those methods which have been most generally accepted and those in which published references can be given."

There are three outstanding differences between the Eighth and Ninth Editions. (1) The divisions of the book. In the Eighth Edition there were seven parts and two appendices; in the Ninth Edition there are only four parts and two appendices. Part I is entitled "Examination of Water —Physical and Chemical"; Part II, "Sewage, Sewage Effluents, Industrial Wastes, Polluted Waters, Sludges and Muds"; Part III, "Microscopical Examination of Water, Sewage Sludge, and Bottom Sediments"; Part IV, "Bacteriological Examination of Water." Appendix I deals with non-standard methods and Appendix II is called "Chemicals and Reagents." (2) Methods of calculation are given for each determination. (3) The format has been changed, the Ninth Edition having two columns on each page.

A new addition for which this reviewer is most grateful is Appendix II, which gives the preparation of the common laboratory reagents. In the Eighth Edition one was referred to the section.

There are two matters in which the reviewer would prefer a change and an addition. The table of atomic weights would be more helpful if it were given in larger print and on the inside back cover. A periodic chart of the chemical elements would be a welcome addition and should also appear either on the inside back cover or front cover.

This reviewer would like to take each method and discuss the differences, if any, between the Eighth and Ninth Editions but space will not permit it.

It has been assumed for a good many years that a person using "Standard Methods" would be a graduate chemist or bacteriologist who didn't need to have all details of procedure or calculations shown. However, it is well known that others do use this book and even graduate chemists if they have had no training in water or sewage analysis may be a little lost at times. In this regard I should like to refer to the water section. In order to keep all determinations of an element together no mention is made of a complete chemical analysis of water in which the following determinations are usually made on potable waters, silica, R_2O_3 (iron and aluminum), calcium, magnesium and sodium and potassium. In the Eighth Edition these are considered together. In the Ninth Edition these elements are all listed separately, and a good many more methods for each element but there is no tie-up from silica to iron plus aluminum to calcium until magnesium is reached. In the latter case it states: "To the filtrate and washing secured after calcium removal (Part I, Sec. 28, A, page 59). . . ." Perhaps this was an oversight in the case of silica, R_2O_3, and calcium, but it is an unfortunate omission.

In the determination of free mineral acids, p. 31 of the Ninth Edition, no mention is made regarding determining this acidity in the presence of sulfates of iron and aluminum. Perhaps it has been found that the single method is more satisfactory or else the editors did not consider that such waters occurred frequently. It is important and I think some mention should

have been made as to why the determination of acidity in the presence of iron and aluminum sulfates was left out.

The standard dilution water for the biochemical oxygen demand determination has been changed. Little stress has been laid on the dilution water for industrial wastes which is now gaining much impetus. A 0.2 p.p.m. depletion is listed for a satisfactory dilution water but this is not so in the case of seeded dilution waters for industrial wastes where the depletion should be between 0.5–2.0 p.p.m. No mention is made that in the case of an industrial waste or sewage containing industrial wastes whose pH is above 8.0 or below 6.5, the sample or diluted sample must be neutralized to be between these limits.

The addition of the glass electrode for pH measurements is a recent development of the past few years and is given as the standard method except for field work.

One of the finest additions to the water section is the discussion on the relation between pH, carbon dioxide, and bicarbonate and carbonate ions. A chart and table showing the relation between pH and fractional activities of alkalinity and acidity constituents is given, pp. 35–36.

Three colorimetric methods for iron are given, bipyridine, orthophenanthroline and thiocyanate methods.

In all colorimetric determinations where spectrophotometric methods have been used the wave-length is given—another welcome addition.

The sewage chemists will be delighted to know that a standard method for grease has been added.

Although the Ninth Edition is not perfect, no new addition will be. This edition is such a complete revision of the previous ones and so much new material has been added that the joint editorial committee and the editor, Dr. George E. Symons, are to be congratulated.

H. Gladys Swope

Sewerage and Sewage Treatment. Sixth Edition. By Harold E. Babbitt. John Wiley and Sons, Inc. Price $6.50.

Earlier editions of this text have found extensive application in the instruction of civil and sanitary engineering students at both undergraduate and graduate levels. The sixth edition retains all of the attributes that have given the book such an excellent reputation as a text and, in addition to the changes that have been made to recognize recent advances in practice, the value of the book as a reference has been enhanced by the inclusion of some new material.

The new edition contains 692 pages devoted to 29 chapters and two appendixes. Space is apportioned to the various aspects of the sewage works field somewhat as follows: historical, project development, preliminary investigations and hydraulics —4 chapters, 80 pages; sewer design—4 chapters, 87 pages; sewer construction—3 chapters, 74 pages; sewage and sludge pumping—1 chapter, 27 pages; sewer maintenance—1 chapter, 19 pages; sewage treatment—15 chapters, 285 pages; industrial waste treatment—1 chapter, 25 pages. Appendix I (20 pages) comprises a list of 147 practical problems that will prove of particular value in classroom work. The second appendix (75 pages) includes a bibliography of 527 selected references and a complete index.

The chapter on hydraulics has been almost completely rewritten, and has been greatly improved thereby. Illustrative problems are used most effectively here to supplement the context.

The chapters on sewage treatment have been brought up to date with respect to coverage of new methods and equipment. A notable improvement has been accomplished in modernizing of the tabulations of plant performance data. It is to be regretted, however, that the timing of this edition made it impossible to utilize the outstanding data and findings which were made available late in 1946 through the NRC report on sewage treatment in military plants.

In general, the sixth edition has been improved throughout by reorganization of the subject matter, by the de-emphasis of some of the older methods and practices, by the recognition of modern trends and by the elimination of the mechanical errors of the previous edition. All of the fundamental values of the original book have been retained, such as its simplicity, directness, balance and painstaking thoroughness. The book is not strong in the chemistry and biological aspects of sewage treatment theory, but these phases are necessarily subordinated to its primary objective as an engineering text.

W. H. Wisely

SEWAGE WORKS EQUIPMENT AND SUPPLIES*

THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Conn.

Copper-Silicon Alloys for Sewage Treatment Equipment

This strong highly corrosion-resistant group of alloys, typified by The American Brass Company's Everdur Metal, has given superior service in the sewage equipment field for nearly two decades.

Everdur, made in several types, consists essentially of copper and silicon, with controlled additions of other elements. The tensile strength, in wrought form, ranges from a minimum of 50,000 p.s.i. for annealed tank plates to approximately 100,000 p.s.i. in cold worked forms. Everdur alloys all possess high fatigue resistance and resistance to corrosion equal to or better than pure copper. There are Everdur alloys adjusted for hot working and for cold work and, with two exceptions, these metals are readily welded by either the oxy-acetylene torch or the carbon arc.

Applications

The principal applications of Everdur for sewage treatment are as follows: coarse and fine screens, swing gates, built-up sluice gates, coarse bar rack aprons, effluent weirs and scum weirs, scum baffles and brackets, troughs, screen hoppers, orifices, bas-

FIGURE 1.—Air filter of secondary room of the Ward's Island sewage treatment plant. Framework of filter structure and filter holders is of welded and bolted Everdur sheet and strip. Retaining mesh for filter is perforated Everdur sheet. Fabricated by American Filter Co., Inc.

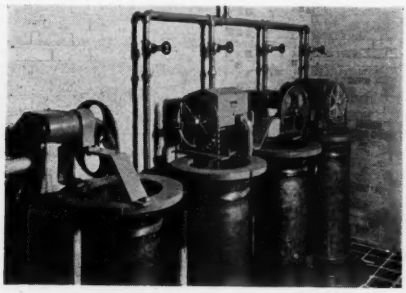


FIGURE 2.—Control mechanism of 12-in. diameter Everdur float tubes. Designed by Krajewski-Pesant Mfg. Corp. for the Ward's Island sewage treatment plant, New York City.

* The material presented here consists of contributions made by advertisers in this issue, and carries no official endorsement. The section is offered as a readership service, affording information on the latest developments in the equipment and supplies finding application in the sewage works field.

kets, anchors, ladders, float gage chain, valve springs, manhole steps, walkways, bars and plates, bolts and nuts, electrical metallic tubing and rigid conduit.

Advantages

Because of high strength corrosion-resistance and weldability, copper-silicon alloys have effected considerable economies in equipment previously made of heavy iron castings. Relatively lightweight wrought sheets of Everdur, assembled by welding, provide much lighter, more easily operated and more durable equipment.

These copper alloys cost less than most high strength corrosion-resistant alloys and not only meet many of the definitely determined corrosion problems of sewage treatment, but also provide the necessary additional protection where the forces of corrosion are variable.

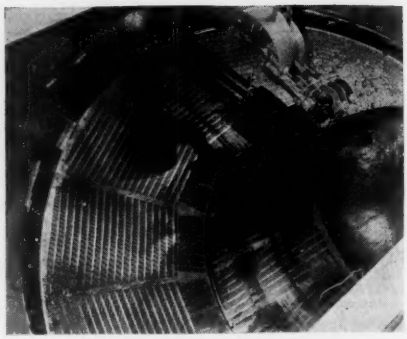


FIGURE 3.—One of two inclined 20-foot diameter revolving disc screens at the Jamaica Sewage Treatment Plant of the City of New York. The slotted plates for the cones and discs were made of corrosion-resisting Everdur Metal by Krajewski-Pesant Mfg. Corp.

AMERICAN CAR AND FOUNDRY COMPANY

30 Church St., New York, N. Y.

In connection with various services being handled in sewage treatment plants, the ACF Lubricated Plug Valve is progressively coming into universal use. These valves have now been installed in many large plants, and have operated successfully for as long as 8 to 10 years handling such services as raw sewage, sludge, by-product gas, compressed air, caustics, hot and cold water and acids. The features which make them highly desirable by operators are their quick turning, full pipe area and their ability to shear off foreign matter suspended in the lading, when being operated.

Other advantages of their design are the absence of pockets or recesses in which foreign particles may lodge, and as contrasted with other types of plug valves, their freedom from sticking which might be due to the wedge effect of a taper. The ACF Lubricated Plug Valve is constructed with a cylindrically shaped plug.

These valves are compact and lend themselves readily to close installation. In this design there are no wearing surfaces exposed to the lading when on flow, all vital seating surfaces being sealed away from the fluid passageway when in the open position.

ACF Lubricated Plug Valves can be supplied in the regular standard rectangular port type having full square-inch pipe area, or they can be supplied with full round port having port area cross-section the same as standard pipe in any given size. The full area rectangular port valves can be supplied in sizes up to and including 16-in., and the full round port up to size 8-inch.

The Company has available, upon re-

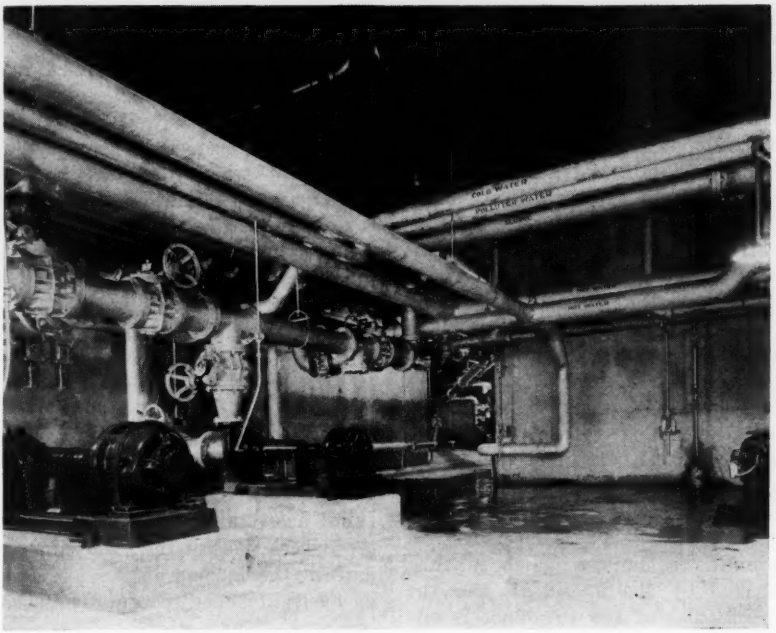


FIGURE 1.—ACF Lubricated Plug Valves in service in the sewage treatment plant at Fort Wayne, Ind. Both worm gear and wrench operated types are shown.

quest, descriptive bulletin No. S–2M–2–46 giving suggested specifications for inclusion of these valves in your designs. The bulletin also contains a list of representative sewage treatment plants that are equipped with them.

THE AMERICAN CONCRETE PIPE ASSOCIATION

228 North LaSalle St., Chicago 1, Ill.

Formed in 1907 at Ames, Iowa, the Interstate Cement Tile Association changed its name to the American Concrete Pipe Association in 1912, at which time national offices were established in Chicago. In 1916 the Association was reorganized as a branch of the Portland Cement Association with special emphasis on investigation, research and the preparation of technical material. By 1945 the industry had grown to such an extent that the Association established offices independent of the Portland Cement Association at 228 North LaSalle Street, Chicago, with activities expanded to include all phases of a trade association.

The Association is the national authoritative spokesman for the concrete pipe industry in the United States and to a large extent throughout the world. It is made up of 150 member companies in the United States, with active members in Canada, Mexico, South America, British Isles, Sweden, Holland, France, Switzerland, Egypt, South Africa, India, Australia, New Zealand and the Hawaiian Islands.

The objects of the organization include the advancement of the art and

science of making concrete pipe; the encouragement of intercourse between men engaged in the manufacture of concrete pipe and the establishment of a central point of referenee and union for those engaged and interested in the concrete pipe industry.

The affairs of the ACPA are managed by a Board of Direction representative of the entire industry, members of which are elected for a 3-year term in such order that one-third of the Board is changed each year. The Board of Direction meets at least once a year and part of the Board, acting as an Executive Committee, meets once a year. This Board has entire charge of managing the affairs of the association, including assessment of dues, determination of policies and employment of staff. The Board is elected by a nominating committee which in turn is elected by the President, and the term of office of the President is one year.

Headquarters are located in the Builders Building in Chicago and include a library of the most authoritative information on concrete pipe assembled anywhere in the world. Activities are concentrated on national advertising, direct promotion and the preparation of authoritative technical literature having to do with the concrete pipe industry. Because of the fact that concrete pipe is used on all types of public improvements the promotional activities are directed to informing the officials and engineers of the federal, state and municipal governments regarding the qualities and performance of concrete pipe. The members of the industry are apprised weekly, by means of a weekly letter from the Managing Director, of all up-to-the-minute news pertinent to the concrete pipe business. From time to time, bulletins having to do with technical phases of manufacturing and laying concrete pipe have been prepared for distribution by the members. Because of the demand for these bulletins it is very difficult to keep them in print. Nevertheless one bulletin having to do with the irrigation and drainage phase of the industry is available to the members at this time, as well as a 275-page manual "Concrete Pipe Lines," a new reprint of which has just been obtained. The demand for these bulletins is so widespread that they are continuously being sent to all states of the union and many foreign countries.

Formed as a loose partnership of members of the industry, the Association is now incorporated in Illinois as a not-for-profit corporation. Its expenses and cost of operation are financed by the members after a schedule of dues has been determined by the Board of Direction yearly. Sufficient funds are retained in the bank to run the Association for the succeeding year and all the income of the Association is spent in the direct interest of the industry. The national advertising is prorated among the leading national technical and engineering journals. Moneys are appropriated for engineering research having to do with hydraulics and the performance of concrete pipe. The direct promotion is carried on by staff members in Washington and, as time and money permits, in every state of the Union and many of the large cities.

Annually the association holds a convention, which is attended by many of the leaders of the industry. The programs of these meetings consist of up-to-the-minute technical presentations, speeches by figures of national prominence in the field of business or general news interest, and a dinner and entertainment for members, guests and their wives. The meeting is preceded by a Board of Direction meeting at which policy matters are determined. Following the Board session there is an open meeting of the Association at which every member company has the right and the duty to approve or disapprove the actions of the Board and

to propose new items for approval or discussion by the entire industry. Because the industry is small, it is possible for each member company to take an active part in the affairs of its trade association.

Concrete pipe was used by the Romans in the year 80 for building a water supply system for what is the present city of Cologne. It has been used continuously since then, with ever increasing adaptability to more and wider fields. The standardization of specifications, improvement in manufacturing equipment and the application of many new methods to the manufacture and installation of concrete pipe have opened up ever-increasing fields, especially during and since the first World War. The industry produces a product which is permanent in every sense of the word. It is so durable that many projects using concrete pipe are being designed with a life expectancy exceeding 100 years. It is made of local materials which are in abundant supply. It is made with local labor under extremely competitive conditions, thus insuring a very economical product. Since its original use in water supply systems, the use of concrete pipe has grown with the growth in population until it occupies a very special sphere, being employed universally in culvert construction, all types of drainage work, for irrigation, for city sewers and for pressure water supply systems.

HOWARD F. PECKWORTH,
Managing Director

AMERICAN WELL WORKS

Aurora, Illinois

Jet Aeration

A new method of air diffusion, the American Jet Aerator,* is now available to users of diffused air in sewage treatment. It represents the latest development in aeration. Designers of sewage treatment plants will find it to be the most efficient and lowest annual cost method available; operators desiring to increase the aeration capacity of existing plants will find it readily adaptable to present structures. In addition to oxygen absorption efficiency surpassing any other method, it cuts maintenance costs to a minimum.

Jet Aeration was originally developed to meet a need for a more economical and efficient method of treating wastes of a large manufacturing plant. Annual cost, with due consideration to operation and maintenance, was a controlling factor. The volume of waste to be treated—several thousand gallons per minute—necessitated such a large installation of equipment that the item of maintenance was of greatest importance and the conventional diffuser plates or tubes were considered undesirable on this score alone. Installation and energy costs of such a large installation were also of prime importance.

Jet Aeration is now made available by the American Well Works for domestic sewage as well as for industrial waste treatment.

One form of the jet aerator is illustrated in Figure 1. The assembly comprises a delivery jet of Venturi section with a high velocity water jet mounted in a divided header. In operation, mixed liquor from the aeration tank or from the final settling tank is pumped through the water jets which discharge through the Venturi nozzle. Air under a pressure slightly greater than the static pressure due to submergence of the header is supplied to the upper compartment and is entrained by the

* Licensed by The Dow Chemical Company.

water jet in a very finely divided state. The fineness of the air bubbles and the extreme turbulence set up by the high velocity jet results in an intimacy of contact between air and liquor attainable in no other way.

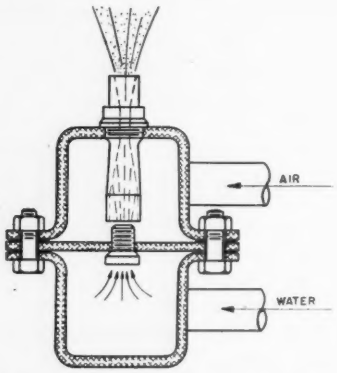


FIGURE 1.—American Well Works Jet Aerator.

The oxygen absorption of ordinary plates or tubes will average less than 5 per cent of the oxygen content of the air supplied. The American Jet Aerator, by contrast, has an average oxygen absorption of more than 20 per cent. Thus this method requires less than one-fourth of the quantity of compressed air required by conventional methods, with a saving in energy for compressing air which will amply offset the energy required by the mixed liquor pump, resulting in a substantial net saving in cost of operation.

There are no fine pores subject to frequent clogging and consequent progressively increasing air pressure required to maintain a given volume of air input. Periodical dewatering of aeration tanks for cleaning diffusers is eliminated at a saving in maintenance cost and more efficient use of the available aeration tank volume. The American Jet Aerator will operate for indefinite periods without attention or maintenance and is no more subject to expensive repair than an ordinary pipeline.

Installation of the jets is simpler and far less costly than that of porous types of diffusers and requires a minimum of skilled labor. Only ordinary pipe fitting is required.

The highest flexibility of operation is provided. The air diffused may be varied over a wide range from 0 to 300 per cent or more of normal air rate. The design of the air system and the selection of the proper number of jets is not critical. The designing engineer is given a wider margin of safety in those cases where reliable data on the oxygen requirement of the waste to be treated are not available.

Bio-Activation Process

The Bio-Activation Process patented by American Well Works, combines the high capacity trickling filter with activated sludge treatment, realizing the advantages of each with none of the disadvantages. The process embraces screening and grit removal as may be required, conventional primary sedimentation, a heavily loaded high capacity filter, usually with recirculation, followed by a short period intermediate settling tank which in turn is followed by activated sludge consisting of aeration, final sedimentation and the usual return and waste activated sludge facilities.

The well proven ability of the high capacity filter to reduce the oxygen demand of carbonaceous material is utilized most effectively and at the same time full advantage is taken of the ability of the activated sludge process to achieve a high degree of nitrification and clarification.

Loads of 3,000 to 4,000 lb. of 5-day B.O.D. per acre-foot per day are imposed on the filter, and under these conditions the greatest removal in terms of pounds of B.O.D. per cubic yard of stone is attained. A high percentage removal of B.O.D. is neither expected nor desired, and likewise the short period of settling following the filter is not expected to provide more

than rough sedimentation. The function of the filter and intermediate tank is to secure high initial B.O.D. removal at low cost, absorb shock loads and condition the waste to the best advantage for activated sludge treatment.

The activated sludge portion of the treatment by reason of the preparatory treatment of carbonaceous material by the high capacity filter is greatly reduced in capacity from that employed for activated sludge alone. Aeration periods from 3 to 4 hours are employed, requiring much less tank capacity and energy input than straight activated sludge.

One of the greatest advantages of Bioactivation is the operational stability of the process. The activated sludge is relieved of the shock loads which are so difficult to handle and septic wastes are converted to a vigorously aerobic condition before reaching the sensitive activated sludge. The operation of the process is quite simple and reliable, and the high degree of treatment attainable only with activated sludge is realized at a very considerable saving both in first cost and operating cost over any other method of treatment yielding comparable results.

The Bio-Activation Process with American Jet Aeration offers the highest degree of treatment at the lowest annual cost.

ARMCO DRAINAGE AND METAL PRODUCTS, INC.

General Offices: Middletown, Ohio

Prefabricated standard steel buildings, known as Steelox Buildings and manufactured by Armco Drainage and Metal Products, Inc., Middletown, Ohio, are expected to find many uses around sewage treatment plants. Standard widths vary from 8 to 24 feet.

In connection with sewer construction and maintenance, corrugated steel sheeting for trenches, and corrugated tunnel liner plates for avoiding costly open trenching are two products which have already demonstrated much merit in hundreds of installations.

Armco asbestos-bonded and paved

FIGURE 1.—Armco Steelox standard building.

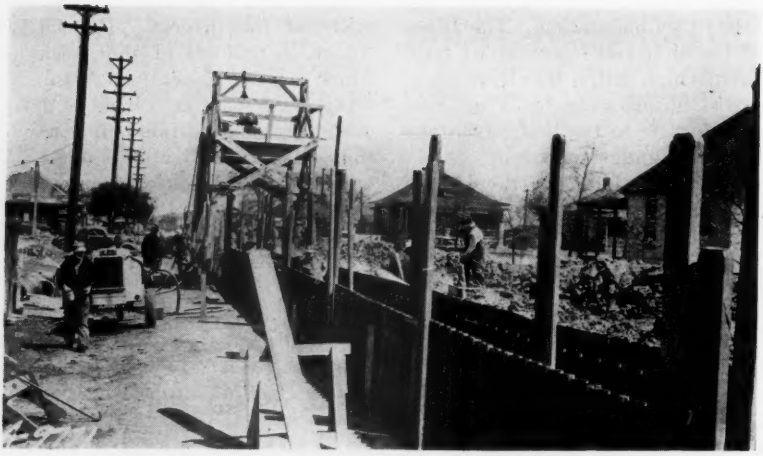


FIGURE 2.—Armco Steel Sheeting for sewer trenches.

FIGURE 3.—Armco Paved Invert Sewer (54-inch) extending 150 ft. into Lake Michigan at Winnetka, Ill.

invert sewers are available now in the pipe-arch form as well as in full round, elliptical and arches. Water-tight joints exclude ground water seepage and thereby lighten the load on the treatment plant as well as reduce the size of the sewers required. Full details may be obtained from the 48-page Armco Sewer Book, which is available on request.

BAILEY METER COMPANY

Cleveland 10, Ohio

Open Channel Meters for Sewage Plants

Modern sewage plant design necessitates the use of more open channel type recorders. These may be applied to flumes, weirs or atmospheric discharge nozzles, and may be direct mechanical registers or remotely located electronic registers.

Mechanical Registers

The Bailey Direct Mechanical Register is located at the float tube or still well; it is actuated by a float and cable arrangement as illustrated in Figure 1. The indicating, recording and integrating features of the recorder are driven by a direct connection to the float and cable mechanism. A specially designed cam which corresponds to the flow head characteristic of the flume, weir or other primary element makes possible the use of a uniformly graduated circular chart.

Electronic Registers

A Bailey Electronic Type Open Channel Meter is illustrated in Figure 2. This type of register results in increased flexibility of application and the easy totalizing of two or more flows. The float and cable operate an electronic transmitter connected to the register, which may be located at any convenient location any distance away from the channel. The transmitter po-

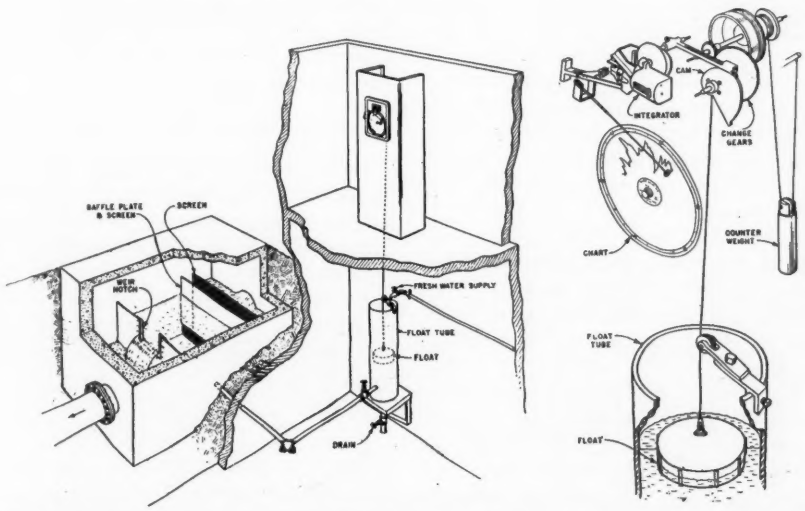


FIGURE 1.—Installation of Bailey Open Channel Meter with a rectangular weir notch as the primary element.

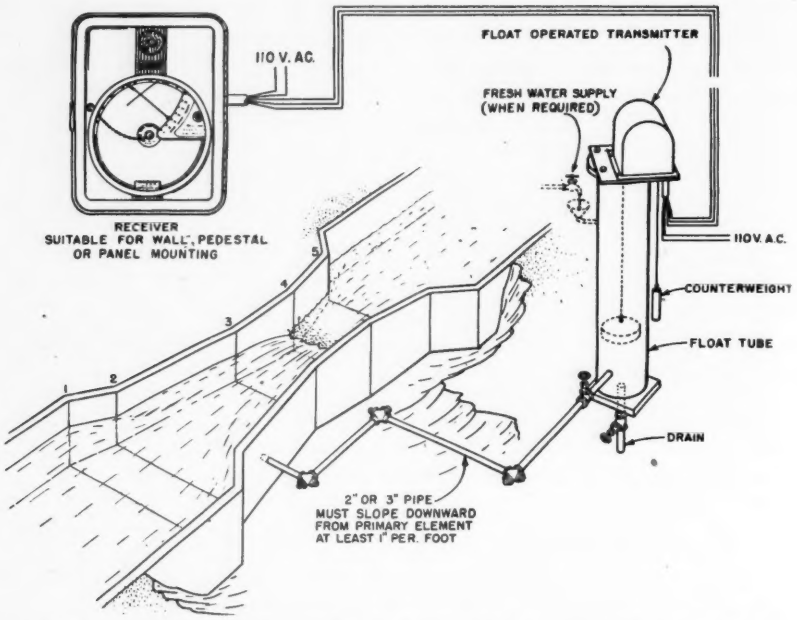


FIGURE 2.—Typical installation of Bailey Electronic Telemeter with a Parshall flume as the primary element.

sitions a movable iron core in a transformer so that the voltages induced in two secondary windings vary with the core's position.

The transmitter windings and the receiver's electrical elements form an electrical bridge. An electronic amplifier and motor control circuit keeps the bridge in continuous balance by operating the motor driven receiver so that its position always corresponds to that of the transmitter.

A standard Bailey Electronic Indicating, Recording and Integrating Instrument, calibrated to read in terms of flow, is used as the receiving register. It is suitable for wall, panel or pedestal mounting.

The Electronic Telemetering System serves as a torque amplifier and requires practically zero input. It provides abundant power for operating the recording pens, indicating pointers, controllers, alarm contacts and other instrument features. In this system there is practically no reaction opposing the transformer core, therefore, accurate operation of the transmitter is insured. The simplicity and sturdy construction of the transmitter makes it possible to locate it outdoors as is sometimes necessary.

Chemical Feed Control

Both types of Bailey Open Channel Meters may be supplied with contacts for the simple control of chemical feed. They may also be used for controlling rate of flow or ratio. To do this, air pilot valves are provided with the instruments. These establish air loading pressures commensurate with instrument readings.

Primary Elements

The Parshall Flume, as illustrated in Figure 2, is the most popular primary element used with Bailey Open Channel Meters. This flume is spon-

sored by the U. S. Department of Agriculture. It is self-cleaning, easy to build, and consistently accurate. Both types of registers may be used with other types of flumes, weirs or other primary elements, as can be seen by Figure 1, which illustrates a mechanical register used with a rectangular weir notch.

Capacity Changes

It is possible to change the maximum capacity of any Bailey Open Channel Meter without disconnecting the metering system. This is done by replacing the specially designed cam and the gears which drive it.

The only limitation on meter capacity is the basic maximum capacity of the primary element and the fact that the head at maximum flow should be at least 5 in. of water. This last is necessary in order to secure adequate power for register operation.

Further Information

Bulletin 62, Bailey Open Channel Meters, completely describes both types of registers, explains their operation, lists their distinctive features and discusses the applications of each.

BUILDERS–PROVIDENCE, INC.

Division of Builders Iron Foundry
28 Codding St., Providence 1, R. I.

RECENT METERING DEVELOPMENTS FOR SEWAGE WORKS

Propellor Type Meter for Clear Effluent

For totalizing the flow of water and clear effluent, Builders-Providence, Inc., Providence, R. I., offers the Propeloflo Meter (Figure 1) whose unique Venturi design creates uniform velocity distribution where the flow meets the propeller. This greatly increases the accuracy of this type of meter over an unusually wide range of flow. Loss of head is reduced to a minimum by streamlining the propeller bracket, hub and nose, resulting in definite savings in pumping costs.

The Propeloflo Meter is complete in itself and may be installed in any position, from horizontal to vertical, as easily as a corresponding length of pipe. The totalizer, protected by a clear plastic bonnet, reads directly in gallons or cubic feet, and the Propeloflo has ample power to drive secondary instruments or proportioning devices. For intermittent flow it is ideal as it resumes operation without attention when the drained line is refilled. Low first cost, simple maintenance, and long life are added qualities of this improved meter.

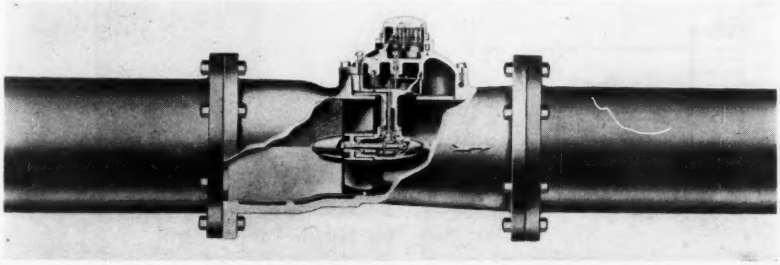


FIGURE 1.—Cutaway view of Propeloflo meter.

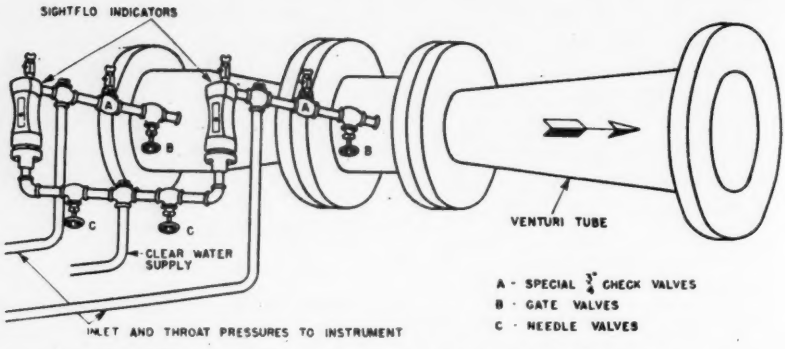


FIGURE 2.—Flush check system for primary sludge meters.

Primary Sludge Meter

To insure continuous operation of Venturi meters handling primary sludge and liquids that are especially difficult to meter, Builders-Providence, Inc., has developed a simple and ingenious flushing arrangement known as the Flush-Check System (Figure 2). Since the annular chambers of the standard Venturi tube would require frequent cleaning under such operating conditions, the usual chambers in the tube are omitted and single large vents are substituted at inlet and throat. A small flow of clear water is injected continuously into the Venturi tube through Sightflo Flushing Indicators and special check valves, effectively preventing solids from clogging the vents and small piping to the instru-

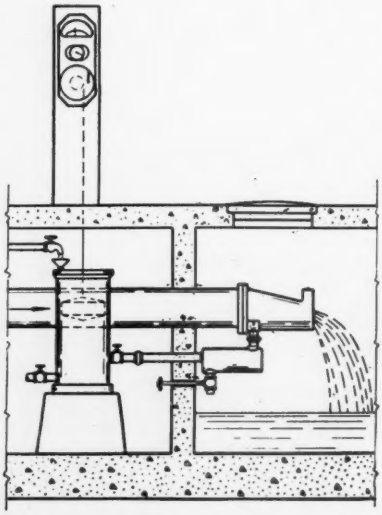


FIGURE 3.—The Kennison nozzle.

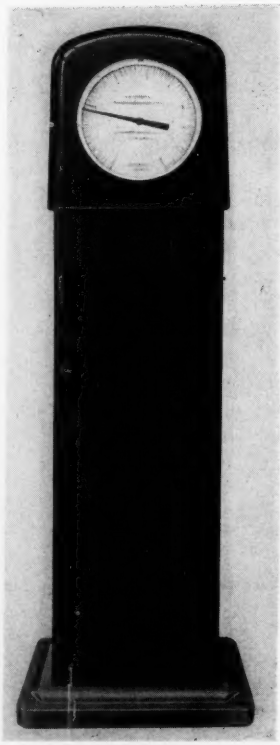


FIGURE 4.—Weatherproof transmitter indicator.

ment. This system, requiring a minimum of attention, has solved the problem of measuring primary sludge in numerous sewage treatment plants.

Meter for Open Flow

The accurate metering of raw sewage, sludge, and trade waste in partially filled pipes and channels has long been a difficult problem. The Kennison Nozzle, made by Builders-Providence, Inc., meets the metering needs of the small sewage treatment plant under such conditions. It consists of an open pipe contracted to a special shape at the outlet end; low head and wide flow range; suspended solids and debris no longer interfere with accurate metering.

A typical Kennison Nozzle meter installation is shown in Figure 3. The nozzle casting is bolted to the pipe through which the sewage flows with free discharge at the shaped end. Leveling lugs are provided on the nozzle and the top is left open for easy inspection or cleaning. At the bottom, near the inlet flange, a relatively large pressure pipe connects, through a sediment chamber, to the open float well of the recording instrument. This instrument may be Builders Type M or Flo-Watch, and for distance transmission the Chronoflo Telemeter is available. Kennison Nozzles are furnished for pipe sizes of 6 in. to 36 in.

Weatherproof Transmitter Indicator

For outdoor installation for metering raw sewage influent or sewage effluent when using a Parshall Flume, weir or Kennison Nozzle, Builders-Providence manufactures a Chronoflo Transmitter-Indicator in a weatherproof case. All operating parts and wiring are fully protected from the weather. This instrument embodying Builders-Providence widely-used Chronoflo system of telemetering is mounted adjacent to flume, weir or nozzle some distance from the plant administration building or office. Particularly suited to this type of remote outdoor installation, the new design eliminates need for a separate meter house. The totalizing and recording receiving instrument may be installed at any convenient location within the plant.

THE CARBORUNDUM COMPANY

Refractories Division
Perth Amboy, N. J.

"Aloxite" Air Diffuser Tubes and Plates

Ten to fifteen years of continuous trouble-free service in activated sludge treatment plants throughout this country and abroad certify the practicability of "Aloxite" diffuser media. These uniform, rugged diffusers have become standard for all types of sewage aeration. They are available for prompt delivery in a variety of sizes and a range of permeabilities.

The trend toward high permeabilities has been met fully by The Carborundum Company, as have the requirements for manufacturing control and product quality. "Aloxite" diffusers are ceramically bonded fused aluminum oxide and are inherently resistant to attack by any solution or gas encountered in sewage treatment. They are capable also of withstanding various cleaning methods used, such as acid treatment, reburning, chlorination, etc.

Uniform air diffusion and low wet pressure loss characteristics are additional properties responsible for highly successful results and savings attained through reduced power consumption.

Tubes have proved more popular

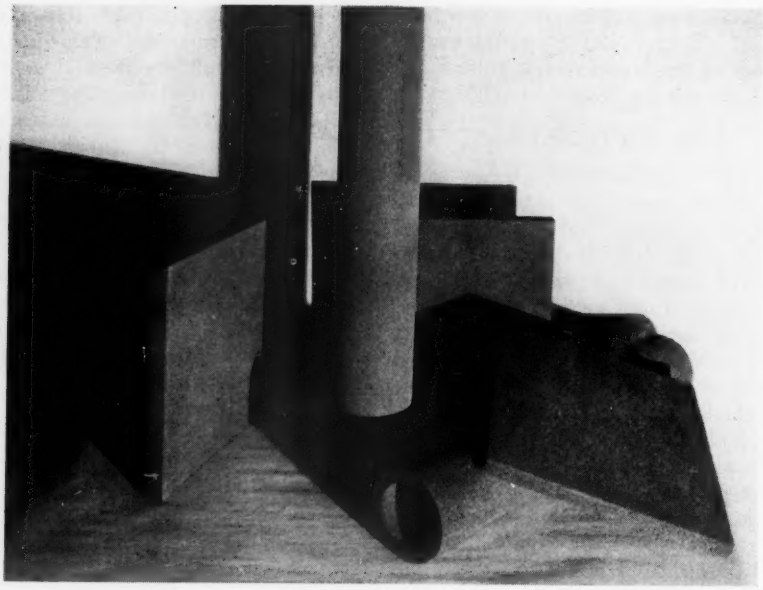


FIGURE 1.—"Aloxite" porous diffuser plates and tubes for sewage aeration systems.

than plates during recent years, especially in the smaller capacity activated sludge plants. Simplicity of installation, ease of handling when servicing becomes necessary and evidence of lower overall cost account for this popularity.

In addition to their major use in secondary treatment by aeration, "Aloxite" diffusers give successful and economical service in channel aeration, preaeration, flocculation, post-aeration and agitation.

The Carborundum Company does not supply complete diffuser tube or plate assemblies with holders and accessories. Leading sewage treatment equipment manufacturers, however, are glad to quote on complete units employing "Aloxite" diffuser plates or tubes.

For further information on "Aloxite" porous diffuser tubes and plates write for Engineering Bulletin No. 1.

CHAIN BELT COMPANY

Milwaukee, Wis.

Rex Triturator

In keeping with its policy of continuous improvement of products, the Chain Belt Company is now offering a Triturator (screenings grinder) of simplified design and improved performance. This unit provides the ideal means of disposal for sewage screenings. Installed either with new or existing bar racks (hand or mechanically cleaned), it provides all the advantages of complete screenings disposal within the system. Its clean-cut shearing action thoroughly disintegrates rags, papers, and all forms of organic solids so that they can be returned to the sewage flow. The work is done with very low water and very low electric current

consumption. The screenings are uniformly reduced to minute pieces by the shearing action of over 2,000,000 blade cuts per minute, and no stringy or large pieces of material can be found in the screenings leaving the machine. Everything passing through the Rex Triturator is so completely disintegrated that it is easily removed by sedimentation and handled as primary tank sludge.

The Rex Triturator has been designed especially for the shredding of screenings from bar racks in sewage disposal plants. The revolutionary performance of the Triturator, in comparison to that of other types of machines previously used for this purpose, is due to its novel design and entirely new operating principles.

The Rex Triturator is a substantially built unit. As illustrated in Figure 1, it consists essentially of a toothed rotor revolving at high speed with the cutting blades in true shearing contact with a semicircular, fixed, perforated cutting screen. Cutter discs of forged steel, housing of ⅜ in. thick welded steel, heavy steel base—these are just a few of the features contributing to its rugged construction.

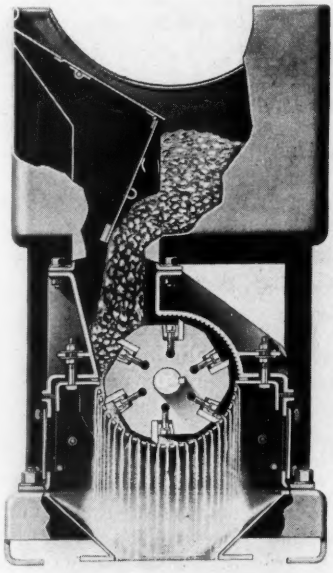


FIGURE 1.—Cross sectional illustration of Rex Triturator.

The Rex Triturator, like no other type of grinder, is accurately balanced. Power is used only for overcoming the resistance of the screenings and the flushing water. Compared with other types of grinders, size for size, the Triturator therefore has greater capacity, uses less power for doing equal work.

The Rex Triturator design and construction offers many advantages in addition to those indicated above, including easily renewable tool-steel teeth; controlled self-feeding by rotor tooth pockets; staggered tooth setting for even distribution of feed and load; reduction in first cost of power lines, switches, and controls; infrequent and inexpensive maintenance; and no vibration.

The Rex Triturator is built in three sizes: machines having four, six, or nine cutting discs. Through selection of the right motor for the right job, and with careful consideration being given to the method of feeding, allowable grinding time per day, and other factors, the Rex line is expanded into nine models ranging in capacity from 20 to 75 cubic feet per hour. Corresponding power requirements vary from 5 to 30 horsepower.

New Grit Collector Wearing Shoes

Grit is well known as the most abrasive material present in sewage, and grit collecting equipment of the general type pictured in Figure 2 "takes a beating" in the strictest sense of the phrase. This is especially true of the wearing shoes that ride the rails set flush in the tank bottom.

An early development of the Chain Belt Company was the separation of the wearing shoe into two parts, the shoe holder and the shoe. Further, with the holder riveted to the bucket or agitating flight, the shoes were de-

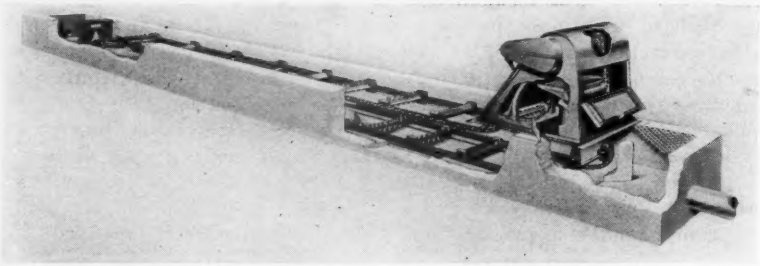


FIGURE 2.—View of typical Rex ME grit collector.

signed to slide on with a dove-tail fit, thus being readily renewable and reversible. Rex Z–Metal was selected for the shoes because of its well known wear resisting properties.

For the purpose of improving wearing shoes even further and particularly to prolong their life, a project was started several years ago and has now been completed. As a result of this study, wearing shoes capped with synthetic rubber will be made available. This synthetic rubber has been selected because of its many desirable characteristics, including high resistance to oils, alkalies, and other potential deterrents normally found in sewage, and to the abrasive action of grit.

The rubber wearing strip is attached to the wearing shoe by means of a special vulcanizing process. A complete bond is effected, strong enough to insure permanence, with no possibility of the two pulling apart under the toughest operating conditions. These new wearing shoes will be made available for existing Rex installations as well as on new equipment.

CHICAGO PUMP COMPANY

2314 Wolfram St., Chicago 18, Ill.

"Package" Sewage Plants, Wide Band Air Diffusion System with Swing Diffusers, Comminutors for Screening and Cutting Coarse Sewage Solids, Hydraulic Grit Removal Systems with Swing Diffusers, Scru-Peller Primary Sludge Pumps, Flush-Kleen Sewage Lift Stations, Raw Sewage Pumps, Plunger Sludge Pumps, Water Seal Pumping Units, Samplers

Chicago Pump Company's exclusive contributions to the handling and treatment of sewage and industrial wastes include "Package" plants for small communities, airports, institutions, housing projects and industrial plants; Wide Band Air Diffusion Systems with Swing Diffusers provide uninterrupted, flexible aeration to meet variable operating conditions of sewage works serving populations of 5,000 and up; Comminutors, which eliminate handling and disposal of sewage screenings and prevent pump and line clogging; Flush-Kleens, which eliminate pump clogging; Scru-Pellers for primary sludge pumping without clogging troubles; and hydraulic grit removal systems which remove all grit dangerous to pumps and other machinery with a minimum of maintenance and labor.

Chicago "Package" plants (Figure 1) give effective, low-cost, nuisance-free complete sewage treatment for populations up to 5,000. They are compact, tailored to requirements, simple to op-

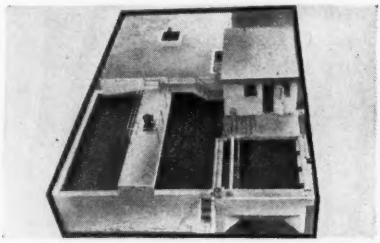


FIGURE 1.—"Package" plant developed by Chicago Pump Co. for complete treatment of sewage in small communities.

erate, odorless, and may be located near dwellings. They were developed twelve years ago specifically to handle the characteristic small community sewage flow and strength conditions, with semi-automatic operation. More than 100 Chicago "Package" plants are in successful operation.

The hydraulic grit removal system with swing diffusers is located in an aeration-type tank before sewage reaches comminutors or pumps. Spiral flow is set up by the swing diffusers at a velocity sufficient to keep organic matter in suspension while heavier inorganics drop to the bottom and roll to the hopper. Grit particles as small as 0.008 in. are removed. The resulting grit is exceptionally clean, containing no organic matter to produce offensive odors. Grit is removed from the hopper by jet pumps.

The Chicago Wide Band Air Diffusion System with Swing Diffusers (Figure 2) was developed more than ten years ago to increase the overall efficiency of activated sludge plants. Swing Diffusers can be raised to the tank walk for tube cleaning and for simple rearrangements of diffuser tube spacing to conform with oxygen demand, without dewatering the tank or interrupting operation. The wide band of diffused air provides greater contact between air and mixed liquor; eliminates center coring; having greater air lift effect, the system develops better tank circulation characteristics. Operating position of diffuser tubes 2 ft. above the tank floor allows lower blower discharge pressure. More than 100 plants are equipped with Chicago Wide Band Swing Diffusers. Many more are installed in industrial waste treatment plants and in chemical processing plants.

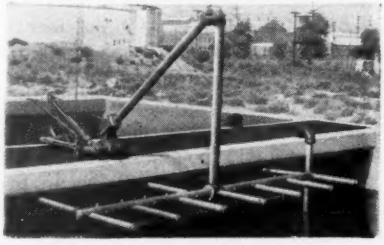


FIGURE 2.—"Chicago" Wide Band Air Diffusion System with Swing Diffusers.

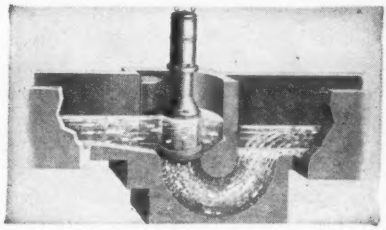


FIGURE 3.—Comminutors eliminate the nuisance of screenings handling and disposal.

Comminutors (Figure 3) were developed to eliminate the nuisance of handling and disposal of sewage screenings. Installed in the influent channel, they provide subsurface automatic screening and cutting of sewage solids without removal from the line of flow. Comminuted particles settle readily with the primary sludge. Installed in lift stations ahead of sewage pumps, comminutors prevent pump clogging by cutting sewage solids before they reach the pumps. More than 1,500 comminutors are in operation.

Flush-Kleen Clog-Proof Sewage Pumps (Figure 4) were developed in 1924. More than 3,000 units have since

been installed in lift stations, buildings and ships. The Flush-Kleen system is clog-proof because a screen in the inlet keeps sewage solids from entering the pump; the impeller handles only strained sewage. The screen is automatically backwashed and the solids are flushed out the discharge pipe. Sewage enters the wet basin through the pump when it is idle. Operation is automatically controlled by float.

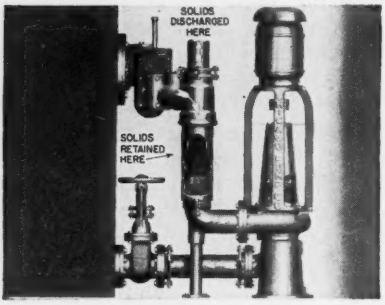


FIGURE 4.—Flush-Kleen Clog-Proof Sewage Pump for lift stations.

Scru-Peller Pumps (Figure 5) were developed by "Chicago" engineers especially for pumping heavy primary sludge. More than 1,000 are in operation. By providing continuous multiple shearing all the time the pump operates, the screw-feed type impellers cut all solids which would tend to clog ordinary non-clog pumps. All shearing edges are stellited for long life and abrasion resistance. Ball bearings on both sides of the impeller keep the pump in perfect balance and prevent vibration and strain on the shaft under heavy loads. All parts of this unit are extra-strong for heavy duty.

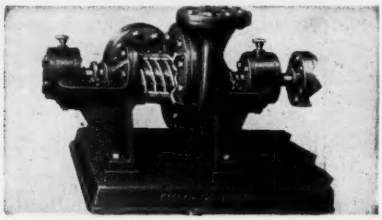


FIGURE 5.—Scru-Peller Primary Sludge Pump.

CLAY PRODUCTS ASSOCIATION

111 West Washington Street, Chicago 2, Ill.

Vitrified Clay Filter Bed Blocks for Treatment Plants

The design of vitrified clay filter bed blocks varies slightly with each manufacturer, but the basic pattern and effectiveness of the blocks is the same for all. They conform with A.S.T.M. Specifications, Designation C 159–45T, Type 1:

"A one-piece filter block suitable for use in constructing a single-course trickling filter floor, which provides continuous drainage channels or ducts through the lower portion of the blocks for the conveyance of liquids from the filter bed and drainage and aeration grilles in the upper portion of the blocks for the passage of liquids from, and air into the filtering media."

Vitrified clay filter bed blocks have the following characteristics which make them ideal for use in trickling filters of all kinds:

1. *Exceptional Strength.* The minimum compressive strength of clay filter bed blocks is between 500 and 600 lb. per sq. in. or 90,000 lb. per sq. ft. . . . ample to support the broken stone or other filtering media that will be placed on them, which under most cases will not exceed 1,000 lb. per sq. ft.

2. *No Displacement.* Being in one solid piece, firmly bedded on the concrete floor of the filter, vitrified filter blocks cannot be displaced by lateral thrusts.

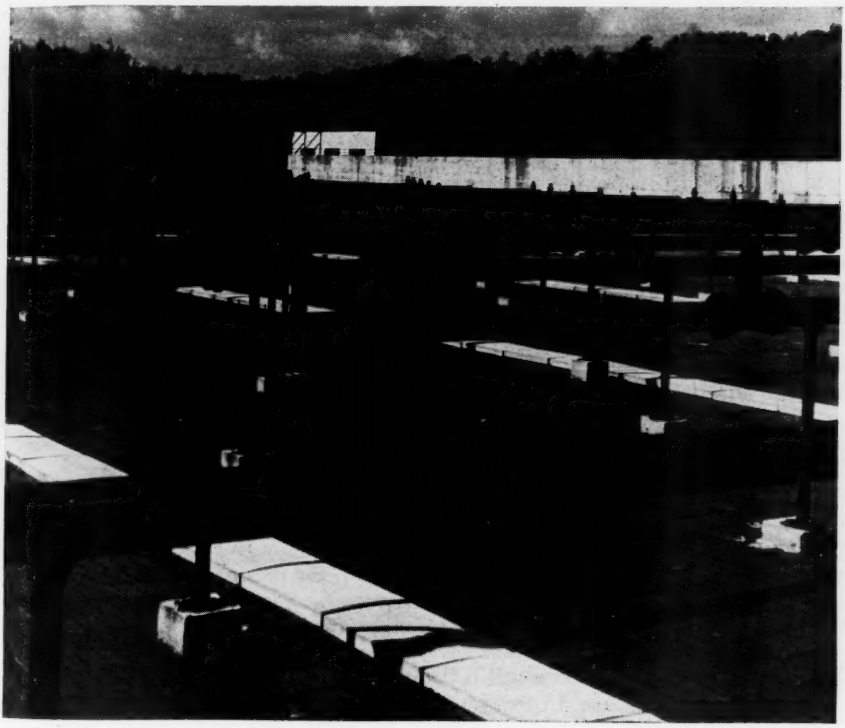


FIGURE 1.—Vitrified clay filter bed blocks provide extra strength, fast drainage, good aeration, and complete resistance to corrosion.

3. *Ample Drainage.* The openings or grilles in the surface of the blocks for the entrance of liquids into the channels are large enough to provide complete drainage. In most clay blocks the ventilation and drainage openings in the surface of the block form 20 per cent or more of the area. There is no chance of the sewage backing up.

4. *Fast Drainage.* The smooth hydraulic surface of the channels or ducts provides fast drainage at small grades.

5. *Good Ventilation.* The large duct and grille areas insure thorough ventilation of the entire filter bed. Vitrified clay filter bed blocks are designed to flow not more than ⅓ full to allow ample aeration.

6. *Ease of Installation.* The uniform, rectangular shape of the blocks make them simple to install. They line up with each other automatically, forming smooth continuous ducts.

7. *Complete Resistance to Corrosion.* Being made of vitrified clay, these blocks are completely resistant to rust, rot and corrosion.

8. *Conformance with A.S.T.M. Specifications.* Vitrified clay filter bed blocks sold by members of the Clay Products Association conform with A.S.T.M. Specifications for Vitrified Clay Filter Block for Trickling Filters (Designation: C 159–45T).

In short, if you want filter bed blocks that provide fast drainage, good aeration, extra strength and corrosion resistance, ask your local supplier to give you the particulars for his design of blocks.

JAMES B. CLOW AND SONS

P. O. Box 6600-A, Chicago, Ill.

POSSIBILITIES FOR MORE EXTENSIVE USE OF LONG LIFE CAST IRON PIPE

At the end of the war, it was discovered that one of the greatest shortages in our building program for G.I. homes and other necessary industrial developments was cast iron soil pipe. James B. Clow & Sons stepped into this breach by the adaptation of their iron-pipe-size cast iron pipe for soil pipe uses. Clow iron-pipe-size cast iron pipe has the same outside diameter as steel pipe, and in 4-in., 6-in. and 8-in. sizes this is the same outside diameter as soil pipe. This I.P.S. cast iron pipe is cast centrifugally in metal molds, so that the outside diameters are extremely accurate and the pipe concentric. In addition, the pipe is annealed after casting so that it can be threaded as easily as steel pipe. There is no sand in the outside surfaces of the pipe to dull the dies. By casting a bell similar to a soil bell on one end of this pipe and furnishing it in 18-ft. random lengths in 4-in., 6-in. and 8-in. sizes, James B. Clow & Sons could offer a pipe to be used for soil pipe. Since these pipes could be threaded (Figure 1), the plumber can

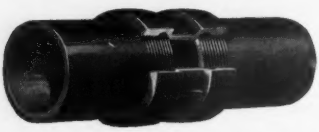


FIGURE 1.—Clow iron-pipe-size cast iron pipe can be threaded for couplings or other fittings.

convert the pipe into double bell pipes or shorter bell and plain end pipes by cutting the pipe, threading it, and screwing on tapped caps; or short double bell fittings could be used as sleeves to use up short plain end pieces. For many purposes the long 18-ft. runs were found to be of great advantage over the 5-ft. lengths of regular soil pipe.

It often happens that a product which is developed for an emergency purpose finds a useful and permanent use after the emergency passes. This, we believe, will be true of this I.P.S. cast iron pipe with integral bell at one end. This pipe will be useful where long lines of pipe for soil purposes are needed; where combination bell and threaded pipe works well into the layout; for house leads from buildings to sewer; and for other purposes that the engineer or architect will discover.

In addition, the bells may be found helpful in the layouts for which this I.P.S. cast iron pipe was originally intended: for downspouts; for conveying liquids corrosive to steel pipe; or for other uses requiring a pipe which is corrosion-resistant from either (or both) inside or outside of the pipe line. This iron-pipe-size cast iron pipe (same outside diameter as steel pipe) can now be had in sizes 3-in. to 8-in., inclusive, in random 18-ft. lengths, for threading for use with couplings and regular screwed fittings and, in addition, in sizes 4-in., 6-in. and 8-in. with the integral hub cast on one end. James B. Clow & Sons, therefore, are now prepared to furnish iron-pipe-size cast iron pipe for the miscellaneous sewerage, plumbing and chemical trades. In the sewage disposal field, the engineer can now specify long-life, strong pipe, made of cast iron, for his water and sewage conveying pressure lines; for sewers requiring strength and tight joints; for lines requiring simplicity of installation and ability to dismantle conveniently; for downspouts; and for lines where threaded joints are useful and corrosion or strength is a factor.

Of course, James B. Clow & Sons also continue the manufacture of their main line of regular cast iron pipe (*not* iron-

pipe-size cast iron) which can be obtained with bell and spigot joints, flanged joints, or mechanical flexible follower-type rubber joint (known as the Clow mechanical joint), and pipe and fittings with a combination of these joints for special layouts.

All of these types of cast iron pipe are fully described in Clow Pipe Economy No. 41, or in special literature which is available upon request from James B. Clow & Sons, 201 North Talman Avenue, Chicago, or National Cast Iron Pipe, Division of James B. Clow & Sons, Birmingham, Alabama.

LEWIS ALK

THE DORR COMPANY

570 Lexington Ave.; New York 22, N. Y.

DORR DEVELOPMENTS—1947

The past year has been a very active one in developing and improving equipment for use in the sewage treatment field. Among the more important items developed, the following are worthy of mention:

Improved Dorr S–7 Clarifier

This new design of clarifier mechanism was developed for tanks 30 ft. to 100 ft. in diameter. Important new features are the use of a cylindrical steel Sifeed column, trussed from rake arms, longer rake blades, steel cage framing, and an improved drive unit. These improvements add greater strength to the unit and make for more efficient operation.

Type M Dorr Digesters

This designates a new line of digesters (Figure 1) in which one or more mixers operate in draft tubes. The mixing capacity is much greater than formerly and is sufficient to turn over the entire contents of the digestion tank in about 30 minutes. In operation, only an hour or so will be necessary for the daily mixing of raw and digesting sludge as well as for the submergence of any scum that may have formed. Supernatant liquor may be withdrawn just prior to mixer operation. Safety devices, including pressure vacuum reliefs, flame traps and explosion-proof motors, are provided.

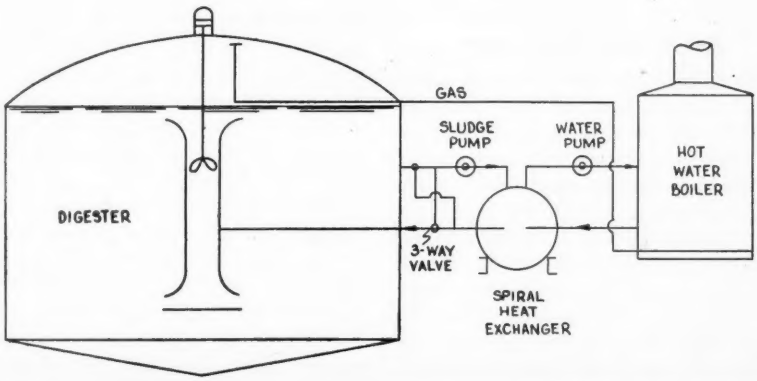


FIGURE 1.—Diagram illustrating Type M Dorr Digester with Spiral Heat Exchanger.

The Type MF digester designates the unit of this type with a fixed roof or cover. The roof may be of steel or concrete. This unit is readily used in conjunction with a gas holder type secondary tank in a Multdigestion System. One or more mixers are used depending on tank diameter.

The Type MA digester combines the Type A (shallow) gas holder with a single central mixer. The gas holder crown is supported by a central drum which also acts as the mixer draft tube. This type unit is designed for smaller plants where sizes from 20 ft. to 40 ft. diameter are required. The gas storage provided is sufficient to hold about 30 to 40 per cent of the average daily production, which should iron out any hourly fluctuations.

The Type MB digester combines the Type B (deep) gas holder with two or more mixing units. Here the mixing units are mounted on the gas holder crown and rise and fall with the movement of the holder, the propellers moving correspondingly in fixed draft tubes.

In all units, the draft tubes terminate above the tank floor so that the bottom digested sludge is not disturbed. Normally, the scum is forced down the draft tube. Periodically, however, the direction of rotation of the propellers may be reversed.

Spiral Heat Exchanger

The Spiral Heat Exchanger is an external digester heating unit manufactured by The American Heat Reclaiming Corporation, and now marketed in the sanitary engineering field by The Dorr Company. As shown in Figure 2, it consists of two concentric spiral passageways. Hot water is passed through one spiral, and digester supernatant liquor or intermediate tank contents countercurrently through the other. The water and digester contents are passed through their respective spirals at relatively high velocity so that high heat exchange values are obtained. The water and sludge spirals are entirely separate so that there can be no admixture of these liquids. Both spiral passages are made readily accessible for inspection by removable flanged cover plates. There are no obstructions in the sludge spiral so that all danger of clogging is avoided.

FIGURE 2.—Spiral Heat Exchanger (4 and 1, hot water inlet and outlet, respectively; 2 and 3, digestion liquor inlet and outlet, respectively).

Trebler Clarifier

The Trebler Clarifier is a standard Dorr Clarifier, separated into two compartments by a vertical diametrically placed partition that extends from above the liquid level down to the mechanism arm supports. One compartment is used for primary settling and the other for secondary settling. In this way, one tank and mechanism will do the same work as two slightly smaller units, resulting in a saving in plant installation costs.

The Trebler unit may also be used in combination with a digester to give a Clarigester in which primary and secondary settling and digestion may be carried out in a single unit.

It may also be operated in conjunction with the Dorr Duofilter, described below, to give a complete two-stage Duofilter plant.

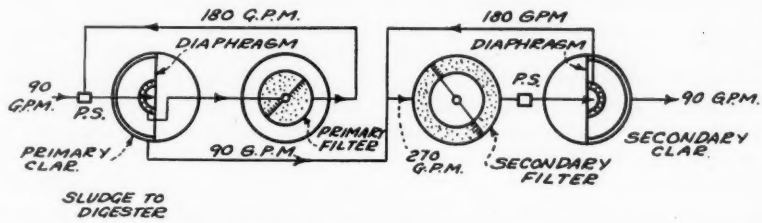


FIGURE 3.—Diagram illustrating Dorr Trebler Clarifier and Dorr Duofilter arranged to provide two-stage Biofiltration treatment.

Dorr Duofilter

The Dorr Duofilter is a concentric arrangement of trickling filters in which the center section serves as a primary filter and the outer ring serves as a secondary filter. Both sections are dosed by means of a single four arm distributor, two short and two long arms serving the inner and outer sections respectively. Figure 3 shows a general arrangement of a Duofilter in combination with a Trebler Clarifier. This combination is ideal for small plants. It is compact and low in installed cost.

Sulzer Disintegrator

The Sulzer Disintegrator is an improved sewage screenings grinder developed by Sulzer Brothers of Switzerland, and marketed in the sanitary engineering field by The Dorr Company. It is essentially a low head pump with fixed and rotating cutting blades arranged in front of a secondary cutting plate so that all screenings passing through the unit are effectively ground. The screenings are raked up a bar screen into a trough or channel that discharges to a sump which in turn connects with the suction side of the Disintegrator. Part of the Disintegrator discharge connects with the screenings trough and serves to flush the screenings into the sump.

THE EIMCO CORPORATION

634–666 South Fourth St., Salt Lake City 8, Utah

Eimco Vacuum Filters

Owing to its physical and chemical properties, sewage sludge yields its water grudgingly, and drainage and evaporation proceed slowly. Therefore, more rapid methods of dewatering are desirable.

Of the methods of dewatering sludge more rapidly than on beds, the one now in most common use is the vacuum filter. In this the water is drawn by suction through a wool or canvas filter medium with openings sufficiently fine so that practically no suspended matter passes through. The general type of vacuum filter consists of a filter drum hung suspended in a vat containing the sludge to be dewatered. Radial partitions divide the filter drum into compartments, each connected by individual pipe lines to a multiple-valve hub so that suction or pressure may be applied automatically and alternately to any compartment as desired.

The surface of the drum is covered with a filter medium through which the water is sucked as the drum revolves through the sludge in the vat, and the solids are left deposited on the surface of the drum in a layer or cake ½ in. or more in thickness. The layer or

cake is dried by sucking air through it after it has emerged from the vat, and then it is peeled from the drum over a scraper. An agitator in the sludge vat keeps the solids there from stratifying; Eimco uses mechanical agitators, but excess air from blowers has been used satisfactorily in some cases.

Vacuum drum filters are built in drum diameters from 18 in. to 12 ft. and in drum lengths from 1 ft. to 16 ft. The filter drum is ordinarily equipped with variable speed transmission and revolves from 1 to 12 m.p.r., depending on the particular installation. The performance is measured by the pounds of dry solids in the sludge cake produced per square foot of filter surface per hour, which varies from 1 to 8, with cake moisture of 60 to 80 per cent. The capacity for a given sludge depends on the accuracy with which the optimum amount of ferric chloride is fed in conditioning the sludge. The drum is covered with a cloth (as the filter medium) which is usually woolen for acid sludge and cotton for alkaline. Cotton, wool and woven glass cloths for strong solutions, and porous rubber for acid and fatty solutions can be supplied. The filter medium in Eimco filters usually is spirally wound with Monel, stainless steel or bright steel wire. Eimco recently has developed a new type of division strip which permits the elimination of wire winding on standard sewage filters.

About 25 per cent of the drum is submerged in the sludge and vacuum is applied from the point of submergence to the point of discharge, as a rule 20 degrees below the horizontal. In Eimco filters, air pressure is applied to one or more of the drum compartments as they descend toward the scraper, thus loosening the cake from the cloth; this air also cleans the pores of the filter cloth.

A vacuum filter installation consists of a sludge pump or bucket elevator, chemical feeders, sludge conditioning tanks, vacuum filter, vacuum receiving tanks, moisture trap, vacuum pump, filtrate pump, blower, filter cake conveyor and sludge cake hopper. Eimco furnishes all as a complete plant, made entirely in their own works. They recommend the use of acid-proof coatings on the surfaces of all sewage filters and auxiliary equipment, as a protection against corrosion.

It is necessary to condition the sludge before filtration to facilitate separation of the solids from the liquid. This is effected by adding chemicals. In most of the recent installations the sludge is elutriated before adding the chemicals, thus reducing the amount of chemicals needed, in some cases by 50 to 70 per cent. Conditioning chemicals used are ferric chloride and lime, or ferric chloride alone, depending on the characteristics of the sludge to be dewatered. Fresh settled and chemically precipitated sludges are best conditioned with lime and ferric chloride. Activated sludge and elutriated digested sludges are usually conditioned with ferric chloride alone. Digested sludges may be conditioned either with ferric chloride alone or with ferric chloride and lime.

The amounts of conditioner used average about 1.5 per cent ferric chloride and 10 per cent lime, on a dry solids basis, for plain settled or chemically precipitated sludge; 1.5 per cent ferric chloride and 8 per cent lime for digested sludges; 1 to 3 per cent ferric chloride for elutriated digested solids, and 3 per cent of ferric chloride only for activated sludge. Some cities have found that purchasing ferric chloride in liquid form eliminates troubles experienced with feeding ferric chloride purchased in crystal form and that chemical costs are lower.

The sludge cake removed from the filter can be dropped onto a belt conveyor, which removes it to the incinerator or other desired point.

Sewage plant records should include

the weight of sludge cake produced each day, and this is most conveniently obtained by weighing it while it is on the conveyor belt. Devices for weighing continuously while the belt is in motion are available. The scale weighs the load continuously as it passes, and transmits to a totalizer the instantaneous variations in weights and belt speed. The totalizer combines and indicates the cumulative result on a dial.

EVERSON MANUFACTURING COMPANY

214 West Huron Street, Chicago 10, Ill.

EVERSON STERELATORS

Sewage control research points out the increasing use and efficiency of chlorine treatment for the following purposes:

1. Disinfection of sewage tank and filter effluent.
2. Control of odor.
3. B.O.D. reduction.
4. Control of sludge bulking.
5. Special industrial waste control.
6. Control of filter pooling.
7. Conditioning of sludge and return supernatant liquid.

The Everson Sterelator is adaptable to a variety of controls developed to function over a wide range of highly variable requirements.

Everson Advantages

One of the advantages of Everson Sterelators, as used in the chlorination of sewage, is the extremely wide range in the ratio between maximum and minimum metering capacities. The Standard Rota-Meter Sterelator, Series 1900 (Figure 1), has a ratio of 10 to 1. This ratio is maximum in all automatic Sterelators. The Relay Rota-Meter (not shown) has a ratio of 50 to 1. The Duplex Rota-Meter Sterelator, Series 2500, Type K (Figure 2), has

FIGURE 1.—Everson Sterelator, Series 1900.

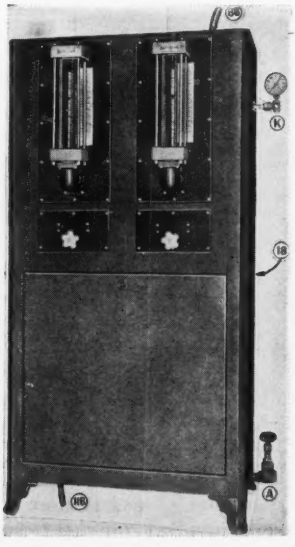


FIGURE 2.—Everson Sterelator, Series 2500.

a ratio of 110 to 1. The Napierian Meter Sterelator, Series 2900, Type S (Figure 3), using the highly accurate Napierian Orifice Meter, has a ratio of 10 to 1.

FIGURE 3.—Everson Sterelator, Series 2900.

Another important advantage—both the Rota-Meter and the Napierian Meter provide a direct *visible* reading of the flow rate of chlorine gas with the highest accuracy.

Controls

The basic Sterelator unit is adapted to a wide range of functional requirements by the use of the following controls: *Manual Control*—use where chlorine feed requirements are more or less constant. *Semi-Automatic Control*—chlorine feed is synchronized to the start and stop cycle of a pump. *Cycle Control*—intermittent operation controlled by electronic timing devices. *Hydro-matic Control*—automatically proportions flow of gas to flow of water, in a controlled range of 5 to 1, within a meter ratio of 10 to 1. *Electro-matic Control*—automatically proportions flow of gas in direct proportion to the water flow, within a range of 10 to 1. Totalizing and recording meters may be placed in the same circuit. *Air-o-matic Control*—automatically proportions flow of gas to water flow, within a range of 10 to 1.

Air-O-Matic Sterelators

One of the latest developments in automatic proportional flow chlorination is Everson's Air-o-matic Sterelator. The automatic proportioning of this machine is controlled with a Pneumatic Differential Pressure Transmitter.

The Pneumatic Pressure Transmitter is an instrument which uses the force balance principle of transmitting or converting a variation in fluid pressure into a proportionate variation in air pressure. The transmitted air pressure is used as the actuating impulse to the Sterelator for the automatic regulation of chlorine flow to proportional water flow.

The fluid flow line pressure is measured by the flow across an orifice plate, flow nozzle, Venturi throat, weir or Parshall flume installed in the flow line.

An air compressor unit supplies air to the transmitter. The transmitter's maximum air requirement is 0.2 c.f.m. Air is filtered and regulated to maintain 20 lb. constant pressure at the transmitter.

The transmitter is designed to deliver air pressure proportional to the square of the rate of water flow in the fluid line. For example: at 35 m.g.d. flow the air pressure established by the transmitter will be 15 p.s.i. At 17.5 m.g.d. the air pressure will be 3.75 p.s.i. At 8.75 m.g.d. the air pressure will be 0.937 p.s.i.

The Air-o-matic Sterelator is available in any capacity from ¼ lb. per 24 hours up to 6,000 lb. per 24 hours, with a meter range of 10 to 1.

FLEXIBLE SEWER-ROD EQUIPMENT CO.

Los Angeles, Calif.

The intense technology which has been a marked aspect of our Twentieth Century has ranged throughout almost the entire field of human works. It has given us new conveniences, new concepts of speed, new methods of transportation, new means of communication, new weapons, new forms of energy—and new problems, such as the maintenance of new as well as old waste carrying lines severely taxed by vast industrial developments of the past few years and subsequent and unpredicted shifts of population.

A considerable amount of this technological advance has also caught hold in the manufacture of sewer maintenance equipment. Changes and improvements have been many and rapid during the last fifteen years and some may be characterized as radical in the last five.

In our own history, Flexible steel sewer rods were first introduced in 1933. Then began a steady development program to achieve the most satisfactory type of coupling, quick to attach, simple in form, strong as the entire string and unhookable except at will.

Motor power for turning flexible rods (Figure 1) was introduced in 1936, with the obvious elimination of hard, slow, expensive, fatiguing labor of another day. Now with a "Flexi-Cleaner" power unit, a two- or three-man team working through a manhole can remove roots, rough joints and other obstructions in "no time flat"—at sewer-line distances up to 800 feet.

Development of new tools and equipment leans heavily on recent manufacturing, metallurgical and engineering progress. New steel alloys, new processes of bending, heat-treating, stress-relieving and tempering have added strength and reliability to equipment. Precision manufacture, and production line technique have provided uniformity and volume.

FIGURE 1.—Two-man crew turning "Flexible" steel rods into a sewer obstruction. Note power drive.

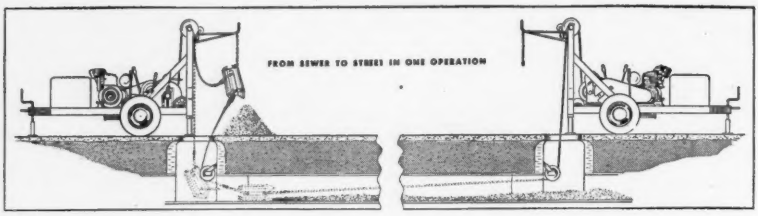


FIGURE 2.—Diagrammatic view of "Flexible" power bucket in operation. Note that clam-type bucket dumps debris on street level for fast, easy removal.

Tests have shown that Flexible steel rods will pull over 4,000 lb. dead weight on a hydraulic scale without parting. They will twist once around in 2 inches before twisting in two. This means that a rod 36 inches long should twist around 18 times before breaking.

Power bucket machines (Figure 2) are becoming steadily more popular for the economical removal of sand, gravel, roots, and other sewer debris. Compact, readily towed, these machines actuate seven sizes and styles of clam-type buckets and bring debris up to street level for dumping. Safe bucket speeds up to 125 f.p.m. are possible, indicating a marked reduction in time and cost ratios for such cleaning operations. Interesting features include the use of 7.7 h.p. Briggs-Stratton air-cooled engines; four-belt clutch drive, with additional booster clutch arrangement to safeguard against sudden overloads or to increase power for hard pulls; back-lash mechanism provided to maintain constant cable tension; foul-proof cable winder and balanced, two wheel trailer chassis mounting.

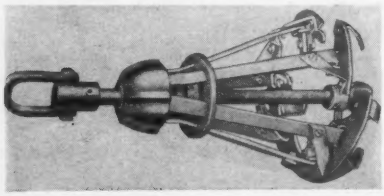


FIGURE 3.—Efficient collapsible-adjustable pipe scraper has proved an excellent tool for removal of roots and hard deposits.

Bucket type machines also operate root cutters and pipe scrapers (Figure 3), vitally necessary tools particularly in instances where no water is available for flushing. Scientific design and rugged strength are requisites because of frequent use in heavily encrusted lines, or for pulling large loads of sand and gravel in sewers, storm drains or culverts.

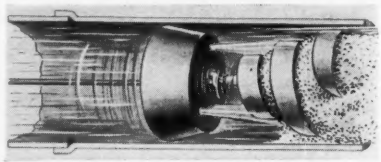


FIGURE 4.—Rubber cup in wide use for sand and gravel removal. The head of flushing water behind tool is propelling element.

The rubber cup (Figure 4) is widely used for sand and gravel removal in sewers 12 in. in diameter or under. A head of flushing water behind the tool is the propelling element.

Many other specific equipment items find necessary applications in this important maintenance work, such as sewer brushes for finish cleaning on peak load lines; Flexible steel lateral locaters; expandable rubber pipe plugs extensively used to shut off flow during man hole reconditioning or pipe line repair; sand traps, pull-outs, special cutting and gouging tools. It is important to remember that each tool has been designed to do a particular kind of maintenance job speedily and eco-

nomically, and to avoid the more expensive dig-up and replacement operation.

During many years of actual experience, only rare instances have been found where modern sewer cleaning tools would not open up stubbornly clogged lines. In the occasional case where tearing up a street was indicated, sewer maintenance equipment pointed out the exact spot for the repair.

GALE OIL SEPARATOR COMPANY, INC.

52 Vanderbilt Ave., New York, N. Y.

The Residual Effects of Oil Pollution

A fact that is often overlooked in observations of the efficacy of devices used for the removal of oils from polluted waters is the continuing evidence of pollution as a result of residual deposits in the receiving stream. An oil separator may be effecting almost complete removals from the wastes being handled, yet the oils, greases and tars which have impregnated the banks and bottom of the stream before treatment was provided may continue for years to cause objectionable conditions in the stream. Considerable time and the scouring effects of many rains are required to eliminate these residual effects.

Early in 1945 a Gale Oil Interceptor and Separator was installed in the Colonie Yards of the Delaware and Hudson Railroad at Watervliet, N. Y. After the unit had operated for a month, the stream water below the outlet continued to show iridescence and a heavy oil sleek. A thorough field and laboratory investigation was then made to determine the concentration of oil in the silt and mud of the stream bottom, and the tendency for this oil to be transmitted to the flowing water.

In May, 1945, a temporary dam was constructed in the stream below the Gale separator outlet, with the object of creating a basin in which to entrap the oil being released from the bottom deposits in the stream. The temporary basin proved ineffective for its intended purpose, but it is significant that the water overflowing from this basin contained 18.2 p.p.m. of oil on May 28, when only 4.7 p.p.m. was found in the separator effluent.

Further studies were made from June 6 to 12, when five samples of stream water 150 ft. from the separator outlet showed oil contents of 12.3 to 45.1 p.p.m. Daily samples of the separator effluent during this same period, when the flow being handled varied from 560 to 675 g.p.m., ranged from 1.6 p.p.m. to 9.1 p.p.m. in content of oil.

Samples of the bottom sediment in the stream were also taken on May 28 at points 50 ft., 150 ft., 500 ft. and 900 ft. below the outlet of the Gale System. Oil extraction tests on these samples showed concentrations based on wet weight of 2.1, 2.3, 7.1 and 2.7 per cent at the respective stations. The volatile content of the mud sample at the 500-ft. point was 29.7 (dry weight); this, together with the fine, silty nature of the soil, was held to account for the high oil content.

The investigation showed conclusively that changes in flow conditions in the stream caused disturbance of the bottom mud through scouring action, causing release of some of the absorbed oil. The released globules rise to the surface and spread in films of various thickness. Furthermore, the banks of the stream are covered with heavy vegetation, which greatly increases the organic content and the oil absorption capacity. Decay of the organic matter

FIGURE 1.—Gale Oil Interceptor serving Colonie Yards of Delaware and Hudson R. R. at Watervliet, N. Y. Stream banks and bottom, soaked with oil discharged before the separator was installed, continue to cause objectionable conditions.

under water by anaerobic decomposition produces gas which may cause oil-soaked particles to rise to the surface, adding to the floating film and iridescence.

Recent examinations of the stream show that there has been marked improvement in the condition of the stream since the Gale unit was installed two years ago. In spite of the heavy rains and melting snows that have acted during this period to scour the old oil deposits from the stream bottom, however, an occasional slight film will appear on the water surface. Several years more will probably be required to dissipate entirely the effects of these deposits.

GENERAL CHEMICAL COMPANY

40 Rector St., New York 6, N. Y.

Aluminum Sulfate for Sewage Clarification and Sludge Conditioning

Sewage plant operators are finding aluminum sulfate extremely useful for two treatment jobs in their plants: (1) for clarification of the raw sewage, and

(2) for conditioning sludge to facilitate dewatering.

Sewage Clarification

The chemical treatment of sewage was extensively practiced during the years prior to the turn of the century. Aluminum sulfate, or just plain "alum," was used in many of the plants at that time. Today our mechanized plants employ chemical treatment with far greater success than the plants of 1900. "Alum" continues to be enthusiastically used as the coagulating chemical in the chemical treatment plant of today.

When aluminum sulfate is added to sewage a chemical reaction takes place between the "alum" and the alkalinity present in the sewage. An insoluble aluminum hydroxide is formed, which is better known as "alum floc." This hydroxide is a gelatinous precipitate that enmeshes fine suspended solids and color in the sewage, and carries such material with it as it settles to the bottom of the settling tank. This action in a sense might be enlikened to a super-fine screen sweeping downward through the sewage and taking with it the solids in suspension. Actually the coagulant does more than this, for it will remove colloidal material, some of the soaps and greases and a portion of the soluble material that is responsible for the B.O.D. of the waste (Figure 1).

A few of the plants using aluminum sulfate for sewage and waste coagulation are: Wood Ridge, Rutherford, Hasbrouck Heights, Somerville, Bound Brook, and Sayerville, N. J.; Circleville, Ohio; Owosso, Mich.; Danville, Ill.; Oshkosh, Wis.; Colorado Springs, Colo.; Santa Fe Springs Waste Disposal, Calif.; and many others which space does not permit listing.

FIGURE 1.—Beaker at left contains a turbid industrial waste. Center beaker illustrates the effect of alum coagulation. Right beaker demonstrates the remarkable clarification obtained by the treatment.

Sludge Dewatering

Digested domestic sludge ordinarily requires 2 to 3 weeks to dry during the summer months and 4 to 8 weeks during the winter months in a large section of the country. Other areas where seasonal rainfalls are experienced know the difficulties in removing sludge from sand beds in a reasonable length of time. Aluminum sulfate is being used to shorten the time required for drying sludge on sand beds. One municipality actually has been able to spade sludge from the beds in 4 days after treating with "alum."

"Alum" reacts with the bicarbonates of the sludge to produce aluminum hydroxide in the sludge. The soupy black sludge is converted to a "curdled" mass. The bond between the water and the sludge solids is broken by the reaction, and a copious rush of water pours from the underdrains of the sand drying bed. In addition to the coagulation effect where the sewage solids are brought together in clumps, the reaction with the bicarbonates releases large quantities of carbon dioxide gas. The gas tends to float the coagulated sludge particles. Flotation of the solids prevents the sealing over of the surface of the sand bed with liquid, thus permitting even faster draining away of the water. The carbon dioxide gas in rising through the sludge mass tends to make it porous and therefore susceptible to faster drying through evaporation (Figure 2). The porosity of the treated sludge is not only evident on the sludge surface, but extends through the depth of the sludge. This has been shown to be true many times

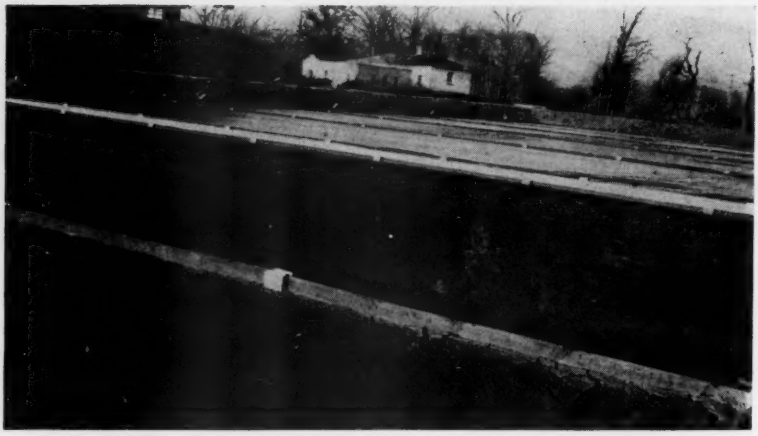


FIGURE 2.—Both beds were poured on the same date. Alum treatment has caused deep cracks to form in the one bed, compared to the smooth wet surface of the untreated bed.

by plants where treated and untreated sludge of the same filling date have been exposed to rain. Rain quickly percolates through the porous treated bed but usually ponds for days on the untreated sludge mass.

Some of the plants using aluminum sulfate for sludge conditioning are Springfield, Mass. (vacuum filters), Stratford, Conn., Plainfield, Wood Ridge and Rahway Joint Meeting Plant in New Jersey, Dayton, Ohio, Aurora, Ill., and many others throughout the middle and far west.

General Chemical Company's Technical Service staff will be glad to furnish details on the above treatments to all operators and engineers operating or designing sewage or industrial waste treatment plants.

GRUENDLER CRUSHER AND PULVERIZER COMPANY

2915–21 N. Market St., St. Louis, Mo.

Sanitary engineers of municipalities have found that Gruendler equipment eliminates the nuisance of undesirable material and waste products clogging sewage and sludge valves and piping. New patented features make possible uninterrupted flow notwithstanding frequent quantities of prevailing rag stock. The Gruendler Shredder is of the swing hammer design with double-end cutting hammers revolving inside a cylindrical shredder plate at 1,200 to 1,800 r.p.m. Capacities are 500 to 8,000 lb. per hour. Motors are direct connected, and range from 5 to 70 h.p.

The Gruendler Shredder is outstanding because of its patented features such as Non Clogging Grate Bars, Safety Tramp Iron Catchers and Improved Water Spray Flushers.

The Gruendler Sewage Screenings Shredder also makes an ideal connection with an incinerator—by grinding, mixing, and preparation in one operation, it prepares product for most efficient combustion and proper feeding.

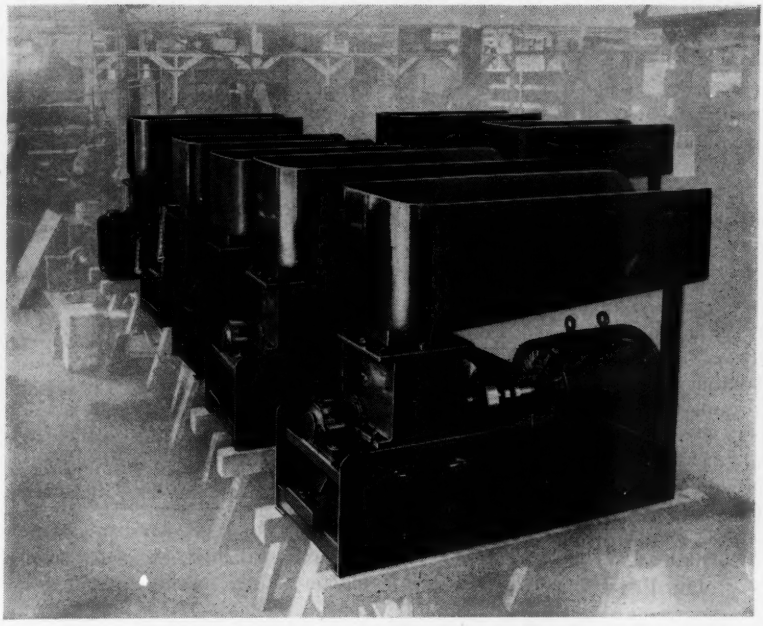


FIGURE 1.—Lineup of Gruendler Garbage Shredder units ready for crates and shipment to the U. S. Navy for installation on battleships and merchant marine; hundreds of these shredders were employed in the war effort.

Gruendler Shredders are dependable and of sturdy construction with sealed bearings to withstand continuous operation. The safety features of the Gruendler Tramp Iron Catcher are noteworthy, since foreign matter such as cans or metal pieces, which is ungrindable, is easily removed through the access door provided. The shredders are built in many sizes and can be fitted in most difficult plant arrangements, taking a minimum of space, and the many designs meet sewage works requirements for higher efficiency. The grinding of sludge to uniform sizes for commercial fertilizer is another operation performed by Gruendler's Hammer-Type Cake Breakers.

Hundreds of Gruendler Shredders have been selected by the U. S. Navy

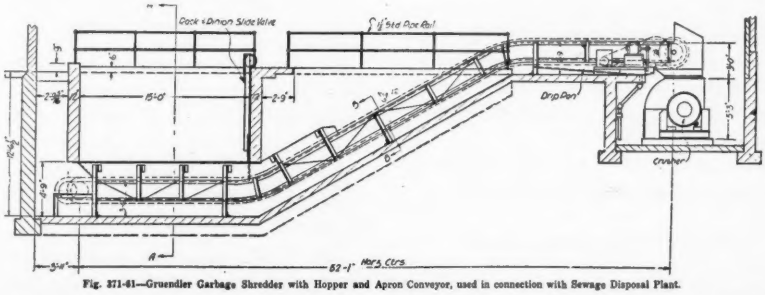


Fig. 371-61—Gruendler Garbage Shredder with Hopper and Apron Conveyor, used in connection with Sewage Disposal Plant.

FIGURE 2.—Diagram showing Gruendler Garbage Shredder with hopper and apron conveyor, used in connection with sewage treatment plant.

as standard equipment on battleships and merchant vessels.

Blueprints and sewage works layouts, together with specifications, will be gladly furnished municipal engineers, plant superintendents or plant designers by the Gruendler Crusher and Pulverizer Company. Address Plant and General Offices in St. Louis 6, Mo.

HARDINGE COMPANY, INC.

York, Penna.

Hardinge equipment has found wide usage in municipal sewage treatment plants, as well as in works provided for the treatment of industrial wastes and for by-product recovery from such wastes. Clarifiers, flocculators, grit removal devices, thickeners and automatic backwash sand filters are among the Hardinge items that are giving outstanding service in these uses.

Hardinge Clarifiers

The Hardinge rectangular or crane type clarifier removes settleable solids from liquid wastes and is particularly suitable where space is limited, or where sludge delivery is desired at one end of the tank. The mechanism is essentially a travelling crane from which is suspended a sludge scraper that lowers when moving toward the solids discharge hopper, and on reversal is raised from the floor to a horizontal position.

The Hardinge circular clarifier features the double spirals or cut flight scrapers which move the settled solids from the rim to the tank center. Mechanism supports consist of I-beams or structural steel superstructure. Underwater parts are available in steel, wood, stainless steel or other corrosion resisting materials. All gears are enclosed and running in oil. Wear at scrapers has proved extremely low.

Flocculating Equipment

For flocculation service Hardinge offers a mechanism comprising slowly rotating paddles on a vertical shaft, designed to hold solids in suspension and create optimum conditions for flocculation. This equipment is used to condition liquid wastes containing suspended solids prior to sedimentation or filtration.

Hardinge Hydro-Classifier

The Hardinge Hydro-Classifier, a grit removal unit, separates suspended matter of high specific gravity from the liquid wastes. While the light solids are carried away in the overflow from the unit the heavy material settles to the bottom where it is gathered to the center and discharged. Continual, low-cost recovery of solids from 48-mesh to 10 microns is being accomplished.

When a minimum of moisture is desired in the removed grit or sand, the Hydro-Classifier may be equipped with a screw dewatering device. This removes the grit from the bottom and deposits it above the tank level in a clean, semi-dry condition.

Hardinge Automatic Backwash Rapid Sand Filter

For use in sewage and water treatment plants, paper mills and industrial wastes treatment, the Hardinge Automatic Backwash Rapid Sand Filter delivers an effluent of high clarity at reasonable cost and with completely automatic operation.

The filter bed is a series of partitions divided laterally into narrow compartments, each connected to a separate effluent and backwash port.

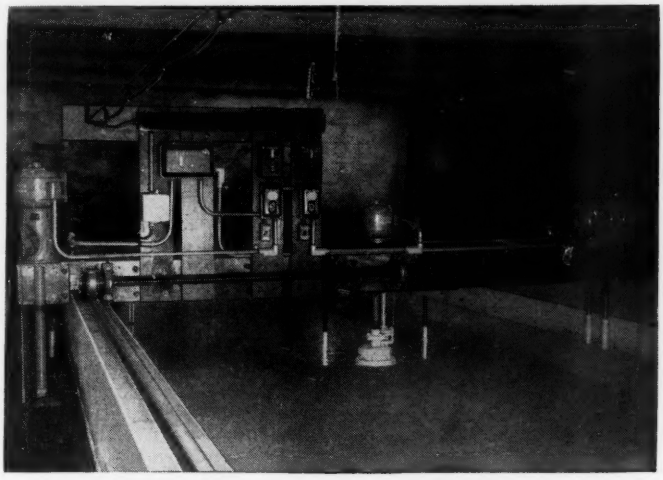


FIGURE 1.—The Hardinge Automatic Backwash Rapid Sand Filter.

The sand filter bed is carried on supporting porous plates or metal screens. The backwash mechanism is a motor-driven, slow moving carriage which operates periodically over the filter bed and is equipped with a backwash pump which takes the filtrate from the effluent channel and pumps it back through the bed. Another pump removes the dirty wash water from the cleaner hood to the wash water launder.

Figure 1 pictures the Hardinge filter in use at the Newton Falls (N. Y.) Paper Mill, where 97.4 per cent of the suspended matter is removed from the raw reservoir water.

Hardinge Thickener

The Hardinge Thickener is similar in design to the circular clarifier, but is more ruggedly constructed for handling a high ratio of solids to liquids. The discharged solids can be thickened to as low a moisture content as is practical.

The "Auto-Raise" drive mechanism, also available for Hardinge Clarifiers, is standard equipment on the thickener. The "Auto-Raise" automatically lifts the scrapers away from all obstructions or an overload of solids in the tank bottom, assuring continuous operation and easy adjustment at all times, and eliminating scraper or shaft breakage.

INERTOL CO., INC.

470 Frelinghuysen Ave., Newark 5, N. J.

Things are back to normal. In all respects, Inertol's products, without exception, are fully equal to those manufactured before the war.

At this point it is worthwhile mentioning that leading sewage treatment plant designers throughout the country are again specifying rubber base chemical-resistant enamels, in colors, on all visible surfaces, in preference to the black bituminous grades previously used. One example of this was recently brought to the attention of the Inertol Company by a prominent consulting engineer, who mentioned that in the future all surfaces visible to the eye,

either submerged or above water, will be painted with white or a light shade. The purpose is, he reasoned, to make the surfaces much more attractive and to show when cleaning is necessary.

Inertol's Chemical-Resistant Enamels are desirable because of the smooth tile-like coating which protects the concrete, discourages deposits or algal growth, and is easy to keep clean. The rubber base enamels are equally as waterproof as bituminous materials, and are far more resistant to sewage gases and chemicals.

INFILCO, INC.

325 W. 25th Place, Chicago 16, Ill.

ACCELO-FILTERS, ACCELO BIOX PROCESS, ACTIVATORS, CLARIFIERS, SKIMMERS, ROTARY DISTRIBUTORS, AUTOMATIC DOSING SIPHONS, AUTOMATIC PROPORTIONERS, ACCELATORS, CHEMICAL FEEDERS, MIXERS, GRIDUCTORS, COAGULATORS, VENTURI TUBES, CONTROLLERS, VORTEX GRIT REMOVERS, AND SAMPLERS

Industrial Waste Treatment

The Accelator, an exclusive and proved development by Infilco, Inc., speeds up waste water treatment and saves up to 80 per cent in space required by older methods. This modern, streamlined unit combines in one compact tank the former separate steps of quick mixing, coagulating, settling, and sludge removal.

Chemical reaction is faster because it takes place almost immediately on the surface of old particles of an already well-coagulated slurry. Clear water rises from the surface of the constantly circulating slurry pool. There is no settling of the solids—no percolating or filtering up through a suspended sludge blanket. Clear, treated water is separated from a dynamic flow of slurry.

Accelo-Filter

Accelo-Filter plants in operation are continuing to prove the advantages claimed for this system of sewage treatment. By recirculating large quantities of unsettled trickling filter effluent directly back through the filter, the aerobic bacteria are returned to the filter in their most active state. Actual operation records prove that B.O.D. reductions are improved.

Odors are kept down by continuous flushing, which removes excess biological gel before decomposition sets in. Fly nuisance is reduced by keeping the filter surface wet with continuous uniform dosing. Clogging and ponding are reduced, due to the continuous flushing which prevents accumulations in the filter. Smaller filters are used in new high rate Accelo-Filter plants than in conventional plants, due to the higher dosing rates. Smaller clarifiers are used in Accelo-Filter plants than those required by other recirculation systems, due to the Accelo-Filter system of direct recirculation through the filter, only. None of the recirculated material reaches either the primary or final clarifier.

The Accelo-Filter system has been successfully applied to existing trickling filter plants to relieve overloading by increasing plant capacity, also to improve treatment results, and to relieve fly and odor nuisances.

Griductor

The Griductor was designed specifically to screen and cut sewage solids in the influent channel and thus eliminate the handling and hauling of sewage screenings, the worst nuisance in sewage plant operation.

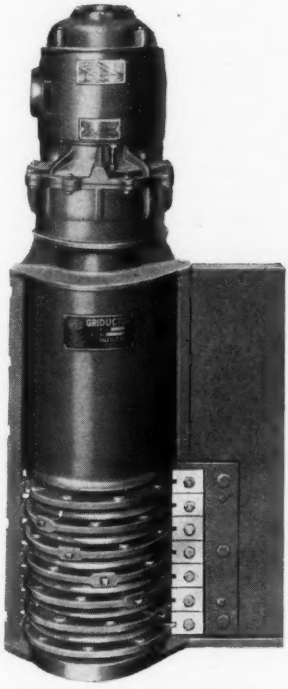


FIGURE 1.—Griductor developed by Infilco, Inc. to screen and cut sewage solids under water and thus eliminate screenings handling and disposal, the worst nuisance in sewage plant operation.

The unit (Figure 1) is installed partially submerged in the influent channel so that all sewage entering the plant passes through its semi-circular stationary screen grid. Circular discs with cutter elements on their edges rotate between the grid bars, thus forming smaller slots. All sewage solids too large to pass through are moved by the rotating discs to stationary cutter bars, where a shearing action between the rotating cutter elements and the stationary cutter bars reduces them to sizes that will pass through. The sheared solids settle in the primary tank and are pumped to the digester. All screening and cutting is done automatically under water, thus eliminating the handling of sewage screenings.

The cutter elements of the Griductor are staggered so that there is only one shearing action at a time. This disperses the cutting load and prevents sudden shocks to the machine. Power costs are minimum.

Vortex Grit Remover

The Vortex Grit Remover is an exclusive development by Infilco, Inc. A vortex circulator in the grit chamber provides the necessary velocities to the

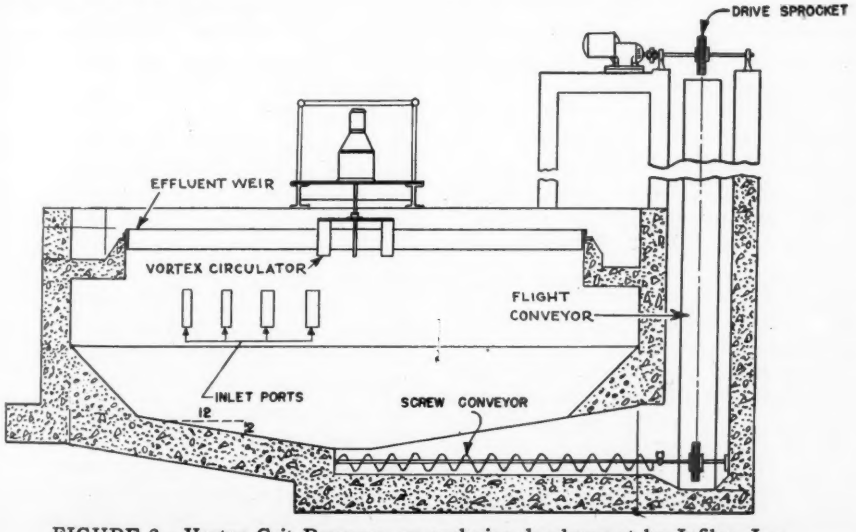


FIGURE 2.—Vortex Grit Remover, an exclusive development by Infilco, Inc.

sewage to obtain selective separation of grit particles so they will be deposited in the radial collection trough in the bottom. The deposited grit is removed by a combination screw and flight conveyor, as shown in Figure 2.

The vortex circulator imparts an upward spiral velocity to the tank contents at the center, with a corresponding downward movement at the tank periphery, providing zones of grit separation adjacent to the peripheral weir and at the grit collection trough in the bottom of the tank.

The screw conveyor moves deposited grit to the foot pit of the flight conveyor, which is so arranged that the chain and sprockets serve to rotate the screw conveyor.

Digester Dome Supporting Covers

Reinforced concrete dome supporting covers are now furnished for both CR and VC Infilco Digesters.

The CR mechanism provides for stirring the bottom sludge layers with continuous movement of the concentrated sludge toward the central sludge withdrawal sump, and for continuous disturbance of surface scum with a consequent stirring action throughout the tank, which greatly improves the distribution of raw solids when added.

The VC mechanism provides continuous circulation, mixing, and disturbance of the upper portion of the digester contents by means of a vortex circulator.

INNIS, SPEIDEN AND COMPANY

117 Liberty St., New York, N.Y.

FERRIC CHLORIDE AS A COAGULANT FOR SEWAGE AND INDUSTRIAL WASTES

The chemical treatment of sewage and industrial wastes is an effective and economical method of increasing the efficiency of primary treatment plants. Such treatment requires but little plant construction or capital investment. It provides a high overload capacity and flexibility in proportioning to produce the degree of purification required. Seasonal loads are handled with the ferric chloride treatment.

Ferric chloride coagulates sewage and industrial wastes, thus causing more rapid precipitation in sedimentation plants and faster filtering through vacuum filtration systems. It is most effective in the pretreatment of industrial wastes which offer change in characteristics almost hourly.

Experience has shown that ferric chloride is also an economical coagulant for sewage and a wide range of industrial wastes.

For Coagulating Sewage

Ferric chloride provides an inexpensive and efficient method of dealing with plant overloads and reduces original plant investment by increasing the capacity of the sedimentation plant.

The accepted procedure in determining the dose of Ferri-Clor required to coagulate a given sewage is to set up "jar tests" with the sewage to be tested. Two-qt. mason jars and stock solutions of ferric chloride and lime, consisting of 10 grams per liter of distilled water, are used. Place one liter of sewage to be tested in each of several mason jars. Add to the sewage in each jar successively larger doses of ferric chloride stock solution. Stir all samples thoroughly for several minutes and let stand for 1 hour. Observation of the several samples will determine the best dosage. If lime is required to provide sufficient alkalinity for satisfactory coagulation, follow the same procedure outlined for ferric chloride. The amount in pounds of ferric chloride or lime required equals the number of ml. used in the selected test times 10 times total sewage flow (m.g.d.) times 8.33.

For Sludge Conditioning

Ferric chloride is accepted as the agent most efficient from the standpoint of performance and cost for the coagulation of sludge prior to its dewatering in the filter.

Using the Buchner funnel test, the time periods required for the vacuum to break with varying quantities of coagulant are recorded. Two to three minutes is satisfactory and 1 to 1½ minutes is very good and should be used for plants where the sludge is held, as in batch mixing.

Various combinations of ferric chloride and lime should be tested until the relative quantities for optimum operation are determined.

The approximate quantities of chemical to be used in the plant can be determined from the laboratory tests, provided, of course, that the same strength chemicals are used in the plant. The quantity of ferric chloride solution in gallons per 1,000 gallons of sludge in the test and the quantity of lime in pounds per 1,000 gallons of sludge will be 42 times the grams used per 200 ml. of sludge.

Preparation of Ferric Chloride Solution

The main difficulty in dissolving ferric chloride arises from the fact that the saturated solution is heavier than water. This means that the liquid in a simple container may have a layer of pure water at the top, even with undissolved crystals at the bottom. To overcome this difficulty, three methods have been developed:

1. Automatic gravity circulation by placing the salt on a wooden grid, elevated or suspended one-half way in the tank.
2. Mechanical mixing by (a) stirring, (b) air agitation, and (c) liquid recirculation.
3. Melting: Ferric chloride melts at 98.6° to 102.2° F. and so can readily be liquefied by relatively small amounts of heat from exhaust or live steam, flue gases, oil, gas or electricity. The dissolved salts can be poured into the water.

FERRI–CL_3OR is Innis, Speiden and Company's registered name for ferric chloride developed and manufactured especially for sewage and water treatment use.

JEFFREY MANUFACTURING COMPANY

Columbus 16, Ohio

New Improved Jeffrey V-Bucket Grit Collectors and Grit Washers

Really satisfactory and efficient grit washing is now possible in any size community by using the Jeffrey system of grit collection and washing. The layout in Figure 1 is recommended for small or moderate size cities.

While partial grit washing is possible in the channel by control of velocities, means provided for stirring grit, etc., our field studies covering small and large cities show that for most satisfactory results the grit should be collected by one mechanism and washed in a separate unit. The layout in Figure 1 accomplishes just that, and by providing controls so that each device operates a minimum of time each day, the life of the collector and washer will be for many years, with a minimum of maintenance.

The grit channel is designed to remove all of the grit above a certain minimum size during conditions of maximum flow through the channel, realizing that with the usual velocity control devices provided at the effluent

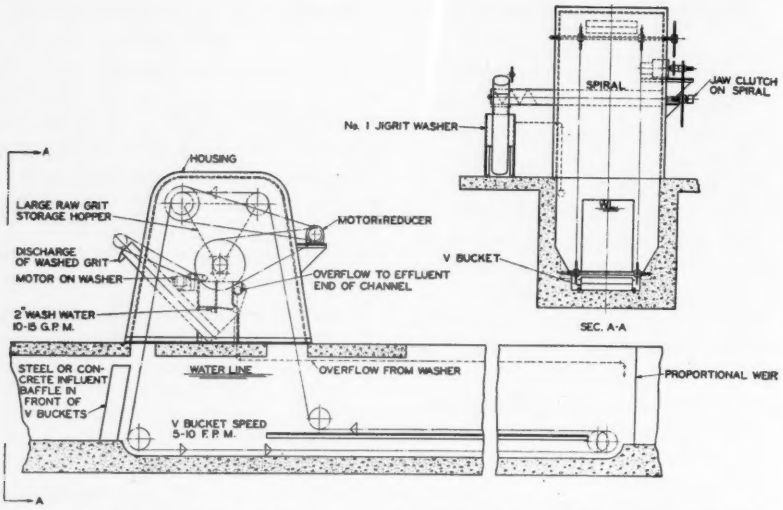


FIGURE 1.—Recommended grit collection and washing layout for sewage works of small or moderate size.

end of the channel, considerable organic matter will settle out during periods of low flow. This is not objectionable if an efficient washer is provided which will remove these later from the raw grit. It is easily accomplished by passing the raw grit through a Jeffrey Jigrit washer, the efficiency of which has been well demonstrated in small and large cities in the United States.

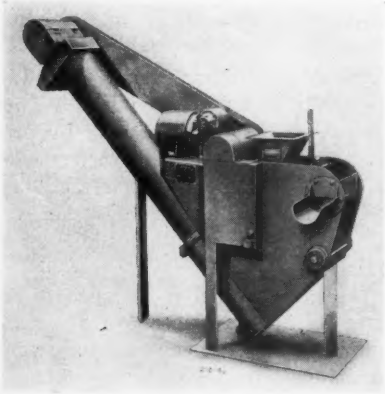


FIGURE 2.—The new improved Jeffrey No. 1 Jigrit Washer.

The improved Jeffrey No. 1 Jigrit Washer illustrated in Figure 2 has a capacity of 20 cu. ft per hour. It will effect an 85 per cent removal of organics, leaving almost no organic seeds and light gravity material in the washed product, and will yield 90 per cent recovery of inorganic grit, which can be used for fill or dumped anywhere without nuisance. The latest design eliminates the rubber diaphragm and many working parts, giving longer life at minimum maintenance expense.

In the layout the grit collector and washer run intermittently, with the collector running a few minutes out of each hour and the washer once or twice a day for short periods of time. Normally the grit collector is operated by time control so that it operates intermittently to keep the channel free of grit. The raw grit is discharged into a storage hopper built in the superstructure at the inlet end of the channel. The bottom of this hopper is provided with a spiral conveyor which provides a constant and uniform feed to the washer whenever it is started. The spiral and washer must operate to-

gether, although the spiral can be provided with an emergency outlet if desired.

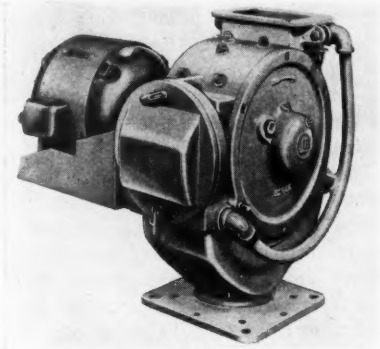


FIGURE 3.—New Jeffrey Screenings Grinder for small sewage treatment plants.

A New Jeffrey Screenings Grinder

Figure 3 shows the new streamlined Jeffrey grinder (S–126–A) designed for the small plant. The grinder is of latest approved swing hammer design, with cutting elements of hardened steel mounted on rotor pins. The cutters can swing back if a heavy obstacle is encountered. Also, the cutters have four cutting edges. V-shaped stationary bars can be spaced to give any desired product. The unit is close-coupled to a 5 horsepower motor. The grinder is provided with a metal catcher, easily removed by loosening two bolts with swing handles. The unit has a capacity of 500 to 750 pounds per hour.

JOHNS–MANVILLE

22 East 40th St., New York 16, N. Y.

TRANSITE ASBESTOS-CEMENT SEWER PIPE

Transite sewer pipe offers many advantages in the installation, operation and maintenance of gravity sewer lines. Among the considerations which make Transite an efficient and economical material for the construction of sewer lines are the following:

Infiltration

It has been authoritatively estimated that as much as 25 per cent of the contents of the average sewer is ordinary ground water that enters the system by infiltration. The cost of treating infiltrated water at the disposal plant is practically the same as for treating the sewage itself, thereby increasing operating costs. Furthermore, the conveyance of this excess water often makes it necessary for engineers to specify larger pipe than would otherwise be necessary, and hastens the day when plants may have to be expanded to provide for increased loads resulting from normal population growth.

Transite sewer pipe, however, offers an answer to the problem of infiltration of ground water through the joints. The type of joint used in Transite lines is usually tight and remains tight in service. Moreover, Transite's long 13-foot lengths cut down the number of joints in the line. Because Transite minimizes infiltration, smaller treatment plants are possible, thereby providing substantial savings in the initial cost of construction.

Carrying Capacity

One of the most important factors in any sewer line is carrying capacity. All other things being equal, a comparison of the flow capacities of two or more types of pipe is best indicated by comparing their respective flow coefficients.

Formed on a polished steel mandrel, Transite sewer pipe has a uniform and extremely smooth interior surface with a friction coefficient of $n = 0.010$. The

resulting high carrying capacity permits savings that may be realized in either of two ways, namely: flatter grades or smaller diameter pipe. If flatter grades are employed, the depth of the trench and the amount of excavation required are lessened, thus making the installation a faster and more economical job. Or, in cases where trenches are deep and the usual sewer line grade maintained, Transite's high flow capacity often makes it possible to use pipe of smaller diameter without reducing the carrying capacity of the system.

Other Considerations

Resistance to corrosion, structural strength and ease of installation are, of course, other important considerations in the selection of sewer pipe.

Because of its special asbestos-cement composition and its unusually low free lime content, Transite sewer pipe is highly resistant to the corrosive action of domestic sewage and to many industrial wastes.

Transite sewer pipe is furnished in sizes from 4 in. to 36 in. in Class 1, from 10 in. to 36 in. in Classes 2 and 3, and from 18 in. to 36 in. in Class 4. Pipe in each class is made to a specific crushing strength, thereby providing for the selection of the most economical classes to meet the specific strength requirements of the line, and often eliminating the need for concrete cradling.

Furnished in long 13-ft. sections and light in weight, Transite eliminates many of the problems encountered in the installation of shorter length sewer pipe. The long lengths greatly facilitate laying the line to an accurate grade and the relatively light weight cuts down handling costs. More footage can be carried per truckload and less time is needed for installation.

For further details on Transite sewer pipe for gravity lines, write for Brochure TR–21A. The Transite Sewer Pipe Installation Manual DS–342 gives valuable information and tabular data pertaining to installation procedures.

FIGURE 1.—Transite's long lengths facilitate laying pipe to accurate grades, speeds up installation and reduces the number of joints.

Transite Pressure Pipe for Force Mains

Transite pressure pipe for force mains assures the same economies of lowered installation and maintenance costs as does Transite sewer pipe. Its high flow capacity ($C = 140$) and freedom from tuberculation help keep pumping costs low. Easily-assembled Simplex couplings provide tight, flexible joints, each capable of 5 degrees deflection.

Transite pressure pipe is available in sizes 3 in. to 36 in. in Classes 50, 100, 150 and 200, for recommended working pressures of 50, 100, 150 and 200 p.s.i., respectively.

For further information on Transite pressure pipe for force mains write for Brochure TR–11A. All of the above mentioned publications may be obtained from Johns-Manville, 22 East 40th Street, New York 16, N. Y.

WILLIAM F. KLEMP COMPANY

6601 S. Melvina Ave., Chicago 38, Ill.

ENDURING GRATING FOR SEWAGE PLANT INSTALLATIONS

The increasing importance being given to modern, labor-saving facilities in public works plants focuses the attention of engineers on the easy installation, with minimum labor, of open steel grating for a wide range of uses.

Klemp Welded Steel Grating provides strong, safe and lasting grating of low original cost and maintenance-free service over long years of the severest duties. It is of one-piece construction in all widths and lengths for every requirement.

Klemp grating (Figure 1) is accurately prefabricated to fit any area, or around pipes, columns, or other obstructions. The hot-rolled steel hexagonal bars, placed at right angles on top of flat bearing bars set on edge and then electro-welded, provide a non-

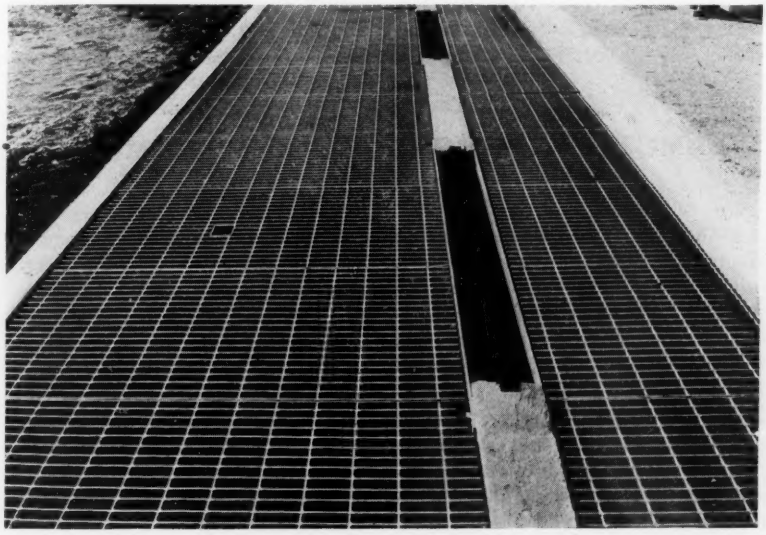


FIGURE 1.—Klemp Welded Steel Grating in service at a sewage treatment plant.

slipping surface that is practically self-cleaning and allows for maximum passage of light and air.

Klemp engineers will suggest the proper grating for specific uses. Further details may be obtained from the manufacturer, the Wm. F. Klemp Co., 6601 S. Melvina Ave., Chicago 38, Ill.

KOMLINE–SANDERSON ENGINEERING CORPORATION

Ridgewood, N. J.

During the past several months, this concern has undertaken a development program covering the application of a Titeflex–Wright Cord Filter to the sludge drier at Plainfield, N. J. In the course of the work an investigation was made regarding the simplification of auxiliaries at present thought necessary in the operation of vacuum filters.

The work has been highly successful. The operation of the cord filter indicates a number of inherent advantages; there is no blinding of the cloth, rates are high, and the unit easily adapts itself to sludges of various densities and grease contents.

The spray drying of filter cake is accomplished effectively by the same style apparatus that has proven so dependable in nine years of trouble-free operation on thickened sludge. In the operation of the drier, advantage is taken of the fact that filter cake is easily extrudable. A hopper-fed Roots type pump revolving at 5 r.p.m. extrudes the cake through two 6-in. pipes onto the spray bowl, where it is broken up into fine particles for rapid drying in suspension.

With respect to the simplification of vacuum filter auxiliaries, the Komline-Sanderson Engineering Corp. has been able to work out a single unit for evacuation of filtrate and entrained air, plus wash water from the cords, eliminating the complement of compressor, vacuum and filtrate pumps, tanks and piping usually required.

The design of the drier, filter and furnace have been incorporated into a single, integral building, with capacities from 20 to 250 tons filter cake per day.

LAMOTTE CHEMICAL PRODUCTS COMPANY

Towson 4, Md.

As in the past, the LaMotte Chemical Products Company is maintaining a complete program of new developments, and improvement of the Standard LaMotte Equipment that has served the sewage works operator so well over the past 25 years. The continuation of this policy has resulted in improved chlorine equipment, embodying the latest developments and recommendations for the accurate determination of free chlorine and chloramines, and the many ramifications of the chlorine problem, including the new Ortho-Tolidine-Arsenite Test. Improvements and accessories for the chlorine and pH tests include a new Plastic Block Comparator which, while possessing many refinements made possible by the application of improved engineering methods, still follows the basic design of the well-known LaMotte Block Comparator, and may be used interchangeably with existing LaMotte equipment.

For the many laboratories that pre-

fer to prepare their own testing solutions, there are three major new developments in the field of standardized chemical reagents.

LaMotte Sulfonephthalein Indicators (Soluble Form)

These are highly purified, crystalline indicator dyes that are instantly soluble in distilled water and represent the first major improvement in the basic pH indicators in over 25 years, since the sulfonephthaleins were first introduced by LaMotte.

To prepare the solution, ready to be used, it is only necessary to weigh and place in a volumetric flask containing distilled water the required amount of dye. The dyes go into solution without heating or the addition of alkali, except for the small quantity required to adjust the solution to the mid-point of the particular range. The following list gives the dyes that are available:

Acid Cresol Red
Meta Cresol Purple (acid)
Thymol Blue (acid)
Bromphenol Blue
Bromcresol Green
Bromcresol Purple
Chlorphenol Red
Bromthymol Blue
Phenol Red
Cresol Red
Meta Cresol Purple (alkaline)
Thymol Blue (alkaline)

New Iron Reagent Tiron

A new sensitive, stable, and widely applicable reagent, has been developed by John H. Yoe and A. Letcher Jones, University of Virginia (*Industrial and Engineering Chemistry,* Analytical Edition, Vol. 16, p. 111–115, 1944), for the colorimetric determination of ferric iron. The reagent may be used in either acid or alkaline medium. In alkaline medium it is sensitive to one part of iron in 200,000,000 parts of solution. In acid solution the sensitivity is one part in 30,000,000.

Ortho-Tolidine Dihydrochloride

Highly purified soluble form of Ortho-Tolidine, recommended in the latest procedures for the determination of chlorine by the Ortho-Tolidine method.

LINK-BELT COMPANY

Sanitary Engineering Division: Philadelphia 40, Pa.

Aerated Settling Tanks

Link-Belt Aerated Settling Tanks have been developed in two designs: (1) tanks in which a preliminary settling period is provided, and (2) tanks in which this settling period is eliminated.

The first design is as shown in Figure 1 and has been installed for handling packinghouse wastes where grease removal is of prime importance. The preliminary settling period is desirable to remove the heavy settleable solids and the readily floatable grease before aeration.

In packinghouse waste treatment, a higher grade grease is recovered in this preliminary settling period. The aeration period aids in the removal of other

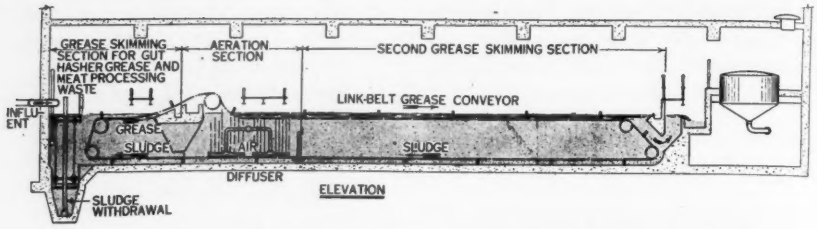


FIGURE 1.—Link-Belt Aerating Settling Tank, with preliminary settling.

greases which do not readily separate from the water and suspended solids.

The second design is as shown in Figure 2 and is recommended for use where increased settling tank efficiencies are desirable in the removal of B.O.D. and suspended solids.

The Link-Belt aerated settling tank consists of a settling tank equipped with a Straightline Sludge Collector for the removal of sludge and floating grease; with porous tubes, through which air is blown, suspended over this collector.

The porous tubes are located on 4-ft. centers across the width of this tank and at a distance of 4 ft. above the tank floor so that the settled sludge will not be disturbed as it is being conveyed along the floor.

As gentle aeration and mixing are desirable, the volume of air required is very low, being only 0.04 cu. ft. per gallon of sewage for an aeration period of 0.5 hour.

The following advantages are claimed for sewage aeration when performed in the Link-Belt aerated settling tank:

(1) Heavy solids which settle in the aeration chamber are removed by the sludge collector. When a separate aeration tank is used, the solids must be removed by draining the tank.

(2) Aeration will increase B.O.D. removal, and gentle mixing will flocculate the sewage solids, thus increasing suspended solids removal.

(3) Grease once separated from the sewage and solids is removed by the sludge collector and is not subjected to remixing, as is the case when a separate aeration tank is used.

(4) Distribution to settling chamber will be over a large cross-sectional area, thus reducing initial velocities.

(5) When chemicals are added to the sewage, a decreased rate of mixing, resulting in maximum flocculation, is obtainable by the control of air supply without fear of detrimental sedimentation.

(6) Initial construction costs will be

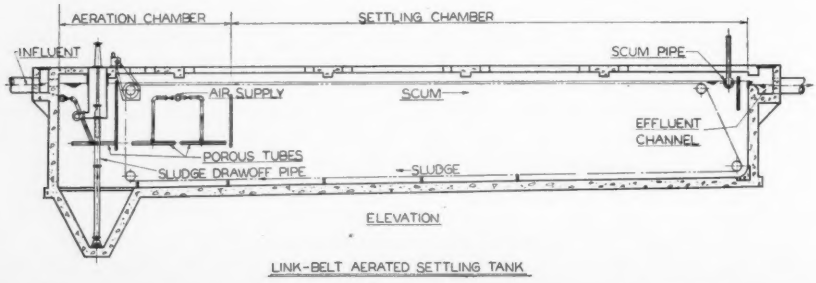


FIGURE 2.—Link-Belt Aerated Settling Tank, without preliminary settling.

at a minimum, as construction of separate tanks is eliminated.

(7) As aeration is accomplished without moving mechanical parts in the sewage, maintenance costs will be negligible.

MABBS HYDRAULIC PACKING COMPANY

431 South Dearborn St., Chicago 5, Ill.

PACKING SLUDGE AND SEWAGE PUMPS

The packing of sewage and sludge pumps presents quite a problem to the sewage treatment plant operator. The nature of the material handled requires that a packing be used which does not become hard in service, because if the packing hardens, the particles of grit in the sludge and sewage imbed themselves on the surface of the packing and thus become implements of destruction.

They begin to cut and score the shafts and in a short time the operator must shut the pump down to renew or replace the shaft. This takes time, labor and expense, and is something that the owner can ill afford under present conditions.

Mabbs Rawhide packing has proved through many years of service to be remarkably well adapted to use in sewage and sludge pumps. This packing, if kept wet or damp, will never harden in service. It will always remain soft and will not hold any particles of grit upon its surface. They are either washed away or work back into the body of the packing, thus preventing the shafts from becoming cut or scored.

A brief description of its manufacture will quickly reveal why Mabbs Rawhide packing does not harden in service. The packing is made of raw cowhides which are cured by a mechanical process which permits the hide to retain its natural oils and makes it very soft, pliable and durable. The hide is dressed down to the correct thickness, cut into strips and braided into a square packing, with the exception that sizes ¼ in. and smaller are made of one solid strip.

Rawhide packing needs no lubrication except water, and when wet it is as slippery as an eel and practically frictionless. It is the ideal packing for sludge and sewage pumps.

The Mabbs Hydraulic Packing Company, Chicago, originators of Rawhide Packing, will be pleased to furnish literature and samples free of charge.

NICHOLS ENGINEERING AND RESEARCH CORPORATION

60 Wall Tower, New York 5, N. Y.

Sewage Sludge Incineration

The Nichols Multiple Hearth incinerator (Figure 1) consists of a cylindrical steel shell mounted on columns and lined with a wall of insulation and firebrick which supports brick hearths one above the other. A vertical air cooled rotating shaft in the center of

the furnace turns horizontal arms above each hearth. Teeth attached to these arms continuously stoke or rabble the sludge. The sludge is charged onto the uppermost hearth and, under the action of the rabble teeth, passes downward through the incinerator, falling from hearth to hearth through drop holes.

The gases produced by combustion of the sewage solids on the lower hearths pass upward through the incinerator in countercurrent to the flow of sludge, and are exhausted by natural draft.

Drying of the incoming sludge is accomplished by the exhaust gases as they pass across the upper hearths.

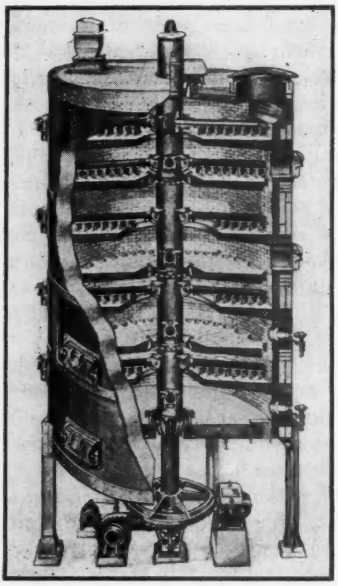


FIGURE 1.—The Nichols Multiple Hearth Sewage Sludge Incinerator.

The one of highest temperature is that at which hydrocarbons are volatilized and burnt. The gases are completely deodorized at high temperature at this point within the incinerator. An excess of air is admitted at all times and thus complete combustion of solids and gases is assured with freedom from smoke and odor nuisance. The wet sludge on the upper hearths serves as an efficient dust arrester, which collects the minute quantities of dust contained in the gases before they leave the incinerator.

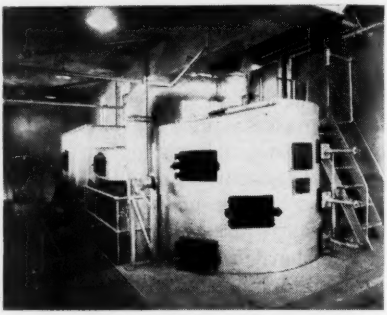


FIGURE 2.—Small, 4-hearth multiple hearth unit at Ashland, Ohio. Handles ground garbage as well as sewage sludge.

Ash is automatically discharged through the bottom hearth and is readily conveyed and stored. It contains no volatile or putrescible matter and the fixed carbon averages below 2 per cent.

Combined Garbage, Rubbish and Sludge Incineration

The Nichols Duohearth incinerator (Figure 3) has been developed for the combined disposal of sewage sludge, along with garbage and combustible rubbish for small and medium sized municipalities.

Garbage and rubbish, charged from a floor above through a charging opening located directly over the center of the furnace, burn in the lower compartment which is a Nichols Mechanically Stoked Monohearth Incinerator (Figure 4). The major portion of the gases is exhausted through a flue at the side of the Monohearth compartment. By damper regulation, any desired portion of these hot gases can be drawn up through the auxiliary flue from the Monohearth and across the drying hearth which is superimposed over the

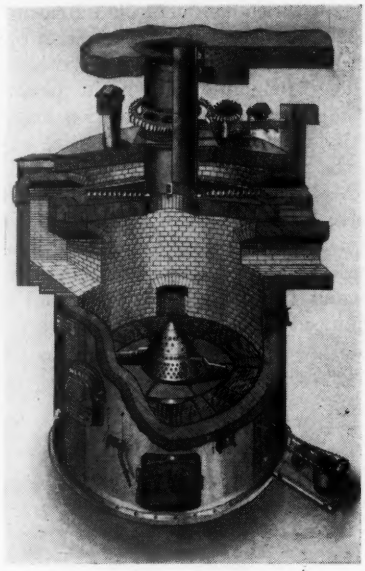


FIGURE 3.—The Nichols Duohearth Dryer-Incinerator.

Monohearth. The hot gases from combustion of the refuse thus serve to dry the sludge and the waste gases and vapor from this upper drying hearth then pass into a combustion chamber where they are mixed with the high temperature gases coming direct from the Monohearth incinerator compartment.

Sewage sludge, which may be filter cake from vacuum filters or centrifuges, or cake removed from open or enclosed drying beds, is fed onto the top enclosed drying hearth. A rotating shaft with arms and rabble teeth plow this material across the hearth, thoroughly exposing it to the hot gases.

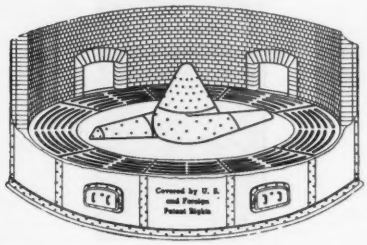


FIGURE 4.—Detail of the Nichols Monohearth Refuse Incinerator.

The dried sludge is continuously discharged by the rotating rabble arms and teeth through an annular opening at the center so that it falls in a continuous stream on to the pile of burning material in the Monohearth compartment, where the mechanical stoking provided by the revolving Monohearth cone and arms assures complete combustion of organics in the sludge.

Modernizing Old Incinerators

The Monohearth principle is not restricted to application in new plants but can be installed in most, if not all, existing incinerators. Rectangular furnaces, basket grate furnaces, and circular furnaces may all be modernized by the use of the Monohearth cone.

NORDSTROM VALVE COMPANY

A Division of Rockwell Manufacturing Company
Pittsburgh, Pa.

NORDSTROM LUBRICATED PLUG VALVES

Nordstrom Valves are particularly suited to the requirements of sanitation departments for use in sewage treatment plants because of their leak-resistant, non-sticking and positive shut-off construction. Made in a wide range of sizes and for various pressures.

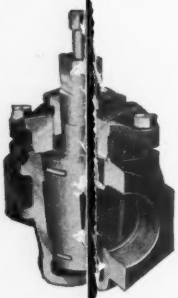
"Sealdport" Lubrication

The "Sealdport" method of valve lubrication forces "Nordcoseal" Lubricant under high pressure between the plug and body, making the valve leak-resistant and freeing the plug to assure

easy operation. Simply turning a screw at the top of the valve completely covers both seat and plug surfaces with a film of lubricant.

Lubricant System in Nordstrom Valves.

Lubricant grooves in the valve body and plug are so arranged that the lubricant cannot be blown from the valve by the fluid or pressure in the line. The Nordstrom method of "Sealdport" lubrication has made practical the use of plug cock valves as large as 30 in. in size and assures the most satisfactory service for sewage plants.



Cut-away view, Nordstrom Valve.

In the phantom view shown, the lubricant grooves on the plug and in the valve body may be clearly seen. These grooves form an interconnecting system which conducts the lubricant to the lower end of the plug in either open or closed positions of the valve.

The principle of high pressure "Sealdport" valve lubrication may be easily traced through the entire valve in the phantom view.

Also is shown plug assembled within valve body and with the especially designed gland and yoke in place. Should neglect to lubricate occur, valve will remain tightly seated because all unbalanced pressure is in a downward direction and can be readily freed by inserting a stick of Nordstrom Lubricant and turning down the screw.

Nordstrom Valve with standard face-to-face dimensions.

Standard Dimensions

Made in one pattern are Nordstrom Valves that have standard gate valve face-to-face dimensions and embody all the advantages inherent to the general Nordstrom line, including the patented "Sealdport" method of lubrication and plug lifting features that make operation easy and positive at all times. It is now economical to replace valves of other types with these lubricated plug valves since they can be installed without altering existing pipe dimensions.

PACIFIC FLUSH-TANK COMPANY

4241 Ravenswood Ave., Chicago, Ill.

P.F.T. Gauge Board for Digestion Tanks

For quite some time it has been apparent that there was a need for a well made and practical gauge board for indicating the liquid level in sludge digestion tanks. It is important that the plant operator be able to observe

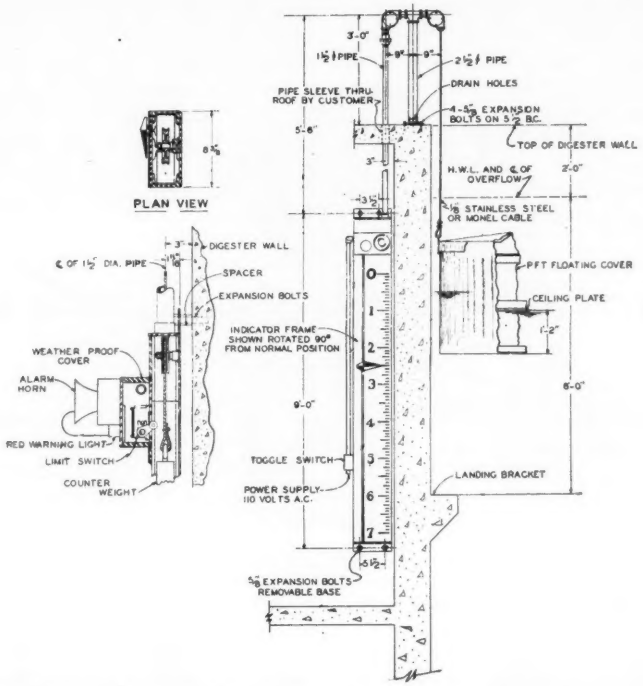


FIGURE 1.—The new PFT Digester Gauge Board, with low level alarm.

in a convenient manner the digester liquid level in order to control the filling and emptying operations.

This is particularly true when the floating cover is nearing the low position at the landing brackets. The warning that the cover is approaching the lowest desirable point eliminates the possibility of withdrawing too much sludge, and thereby making it possible to draw air into the digester. Having this and other features in mind, the Pacific Flush-Tank Company has developed a gauge board which will fill the requirements of such equipment.

The indicating board (Figure 1) consists of a frame fabricated from structural steel shapes and plates, on which is mounted an indicating scale made of stainless steel with figures and scale etched thereon and with etched recesses filled with black enamel. The scale is graduated from 0 to 7 feet to read in feet and inches, with figures of a height of 3 in. at each foot level. A red and white enameled target indicates the feet and inches remaining between the liquid level in the digester and the overflow. By means of a weighted target, counterweight, and pulley, the target travels in the same direction as the floating cover.

The counterweights within the indicating board frame are connected to each other and to the floating cover by ⅛-in. diameter stainless steel or monel metal flexible cables. The cable between the indicating board frame and the floating cover is enclosed in a weatherproof conduit with 4-in. minimum diameter free running pulleys at all changes in direction of the cable. The conduit is supported by a 2½-in. flanged pipe base bolted on the top of the digester wall and arranged to give

adequate clearance with the floating cover at its highest position. The cable is attached to the floating cover by means of a suitable clip attached to the flashing bar.

A low level alarm is provided which will automatically sound when the floating cover drops to within 6 in. of the landing brackets. The alarm consists of an alarm horn and limit switch, positively actuated by the counterweight within the indicating board frame. A toggle switch is provided for shutting off the alarm horn, with a red warning light, mounted alongside the alarm horn, which will be lighted at all times that the alarm horn is not in circuit.

PITTSBURGH EQUITABLE METER DIVISION

A Division of Rockwell Manufacturing Company
Pittsburgh, Pa.

Pittsburgh-Empire Water Meters

Pittsburgh-Empire Water Meters have for years been used by large and small municipalities alike throughout the country. Their excellent construction, maintained accuracy and long life, have been thoroughly proven on hundreds of thousands of installations.

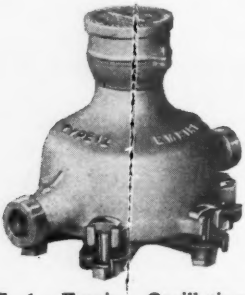


FIGURE 1.—Empire Oscillating Piston Water Meter.

In sewage treatment plants they are recommended for measuring the heated water circulated through digestion tanks, and all cold water pipe for various uses throughout the plant. Hot water meters are of a special construction to operate under high temperatures.

Emco Meters for Sewage Gas

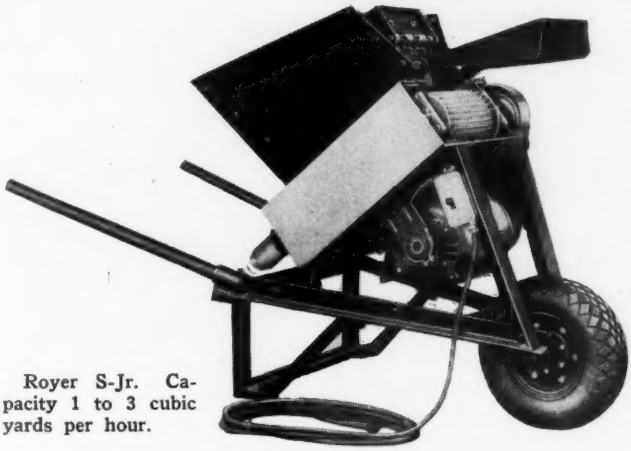
It has become common practice in the design and operation of sewage treatment plants to utilize the gas generated during sludge digestion as a source of heat and power. Since modern engineering methods have demonstrated that accurate measurement is a necessary part of the control of any process, the metering of this gas is an important matter and the choice of meter should be given careful consideration.

FIGURE 2.—Emco Sludge Gas Meter.

Experience has proven that the conventional meter used for measuring manufactured and natural gas will not operate satisfactorily on this type of service due to the destructive effect which sewage gas has on materials commonly employed in the construction of gas meters. For this reason Emco meters for sewage gas are especially constructed from materials which laboratory tests and years of field experience have proven resistant to the action of this gas. The outer case is of heavy cast iron with interior coated with a special preparation. A special tannage and treatment is given to the diaphragms.

THE ROYER FOUNDRY & MACHINE COMPANY

Kingston, Pa.



Royer S-Jr. Capacity 1 to 3 cubic yards per hour.

Convert Sludge Disposal Costs to Revenue

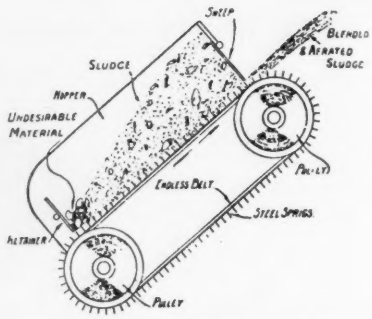
Preparing ready-to-use, marketable fertilizer with a Royer Sewage Sludge Disintegrator costs less than burying or incinerating—give the finished product away and you're money ahead . . . sell it and you earn income to make improvements or reduce plant operating expenses.

Under stringent wartime conditions, sludge fertilizer proved its superior plant-growth-stimulating values—now it's in demand by growers. All sludge is rich in nitrogen—digested or activated it's also rich in phosphoric acid and potash. The Royer quickly and cheaply converts lumpy, caked sludge from drying beds to velvety, uniform, nutritional material that sells readily. There's a Royer capacity and drive ar-

Royer at city of Omaha sewage plant.

Model No.	Capacity (cu. yd./hr.)	Portable or Stationary	Drive
S-JR.	1 to 3	1 wheel portable	electric motor
S-JR.-G	1 to 3	2 wheel portable	gasoline engine
NSB-2	3 to 6	2 wheel portable	electric motor
NSB-4	3 to 6	4 wheel portable	electric motor
SK	3 to 6	2 wheel portable	belt-to-tractor
NSH	3 to 6	4 wheel portable	gasoline engine
NSC-2	5 to 8	2 wheel portable	electric motor
NSC-4	5 to 8	4 wheel portable	electric motor
NSO	5 to 8	4 wheel portable	gasoline engine
SM-2	5 to 8	4 wheel portable	belt-to-tractor
NSD-P	8 to 12	4 wheel portable	electric motor
NSD-S	8 to 12	stationary	electric motor

Royer Sludge Disintegrator at Wisconsin Rapids' modern sewage treatment plant.



Action of Royer "combing belt" on sludge cake in hopper.

rangement to meet every plant requirement as shown in the table below.

Simple, positive action of Royer "combing belt" assures high-speed, quantity production of prepared sludge. One to three men, depending on size of machine, shovel sludge from drying bed into wide, low hopper. Material falls onto endless belt on which are mounted staggered rows of chrome-molybdenum sprigs or teeth. Action of rapidly-moving sprigs quickly disintegrates sludge to uniform pea size; removes additional moisture; aerates; mixes in chemicals if you want an even higher profit fertilizer; discharges by centrifugal force for final aeration direct to pile, bag, or truck—sticks, stones and other trash gravitate to lower end for removal by periodic lifting of retaining gate.

Long service assured by rugged welded construction and dust-proof, anti-friction bearings. Get the facts—send for free Sewage Sludge Datalog.

SIDU COMPANY

174 La Verne Ave., Long Beach, Calif.

Sewer Cleaning with Rubber Balls

The use of rubber balls for the cleaning of sewers is not new. Their use on the Pacific Coast was inaugurated by the Los Angeles County Sanitation Districts following the construction of new lines. An ordinary soft rubber beach ball, wrapped in canvas or burlap, or enclosed in a canvas sack with a tag line attached, was used for ridding the lines of sand, dirt or other debris remaining after construction was completed.

The balls were placed in a manhole and allowed to enter the line. The entry of the ball closes the outlet and causes a head to build up in the manhole behind the ball. The resulting pressure forces the ball through the line and permits it to contract slightly, thus permitting the passage of water or sewage under it.

This operation was satisfactory and the lines were cleaned thoroughly and expeditiously. However, it soon became evident that replacement of the cover which was soon worn off, was a problem. It was found that needles, pins and other sharp particles penetrated the cover and punctured the ball. It was essential that some control of the ball during its passage through the sewer was necessary, and that some means be devised by which a tag line could be attached, either to

the cover or to the ball itself. As a result of these problems the Wayne Ball was developed.

The Wayne Ball (Figure 1) is scientifically designed and constructed of specially compounded high quality rubber of thickness varying with the diameter of the ball. Lugs are moulded directly into the ball to which the tag line is attached. The Wayne Ball is so constructed that as the pressure in the line is increased as a result of an increase in head, the interior pressure of the ball is overcome, causing it to change its shape slightly so that it resembles an elongated plug. This permits a jet of water to be released, the velocity of which automatically increases as the hydrostatic head is raised.

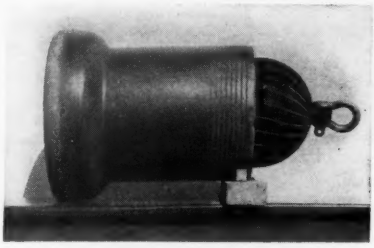


FIGURE 1.—Wayne Ball placed in section of 8-in. pipe. Note diagonal ribs and method of attaching tag line.

Unlike the conventional beach ball, the Wayne Ball does not indent if an obstruction such as joint fins is encountered, but on the contrary the ball exerts sufficient pressure to break the offending obstruction. In the event the obstruction is obstinate, the ball may be partly withdrawn and quickly released. The momentum of the impact upon release forces the ball along the line, carrying with it the offending obstruction. In case of a broken pipe which completely stops progress of the ball, the location of the break may be accurately determined by withdrawing the ball and measuring the length of the tag line from the manhole to the point where the obstruction was encountered.

Roots, too, are removed as the result of the use of the Wayne Ball, and every kind of debris from concrete aggregates resulting from the disintegration of concrete pipe, to whole bricks, to say nothing of pieces of pipe and almost every possible type of material that can find its way into a manhole are quickly cleaned out of the line. Within the past few days (April 9, 1947) a maintenance crew in Long Beach, Calif., removed from a run of 440 ft. of 12-in. sewer, over 3 cu. yd. of sand, muck and sludge in 32 minutes. Daily runs of from 3,500 ft. to 3 miles are

FIGURE 2.—Service of truck of Sewer Maintenance Division, Long Beach, Calif.

FIGURE 3.—Pumping equipment used in handling grit expelled by the Wayne Ball. The truckload shown was removed from 440 ft. of 12-in. sewer.

not unusual, and once the line has been "balled," subsequent cleanings, which should be effected at reasonably frequent intervals, permit of much greater speed.

The surface of the Wayne Ball is constructed with rubber ribs placed diagonally along the periphery in a manner that provides a squeegee effect, thereby removing slimes from the walls and top of the pipe, in addition to forcing the removal of sand, grit, rock and other materials. It has been proven that the regular use of the Wayne Ball has materially reduced the number of trouble calls resulting from stoppages as evidenced by reports from Los Angeles and Long Beach sewer departments. It has been observed, also, that odors have been eliminated as a result of the removal of bacteria breeding slimes.

A dirty pipeline is responsible for many of the headaches that confront those who are charged with the responsibility of maintaining a modern sewage collection system. Slimes are the result of dirty and neglected pipelines, although deposits of sludge also set up seeding places in which bacteria thrive. The result of such accumulations is the formation of hydrogen sulfide gas, the ravages of which are so well known as to require no further comment.

In an article in SEWAGE WORKS JOURNAL (July, 1946; p. 618), Pomeroy and Bowlus state: "If sewers contain considerable amounts of deposited sludge, anaerobic decomposition of such sludge may produce sulfides. This condition is to be distinguished from the production of sulfides by the slimes which consist essentially of fungi and other microbes. A further disadvantage of deposits of sludge and other debris is that they retard the flow. In small lateral sewers the holding back of the sewage by partial stoppages is often the cause of high sulfide concentrations. *Periodic cleaning is an important procedure for sulfide control in such cases.*"

SIMPLEX VALVE AND METER COMPANY

68th and Upland Sts., Philadelphia 42, Pa.

The Simplex Type S Parabolic Flume Meter

This meter was designed to meet the specific need of measuring with greatest degree of accuracy possible within commercial limits, the flow of all liquids through partially filled pipes, sewers or channels where free-flowing conditions exist.

It is applicable for use at points in both industrial and municipal plants to obtain accurate measurement of flow under adverse conditions where previously recognized methods of measurement could be applied only with great difficulty, if at all. The flume section itself is constructed of cast iron, with circular inlet end and with the interior presenting a smooth transition from circular to parabolic form at the outlet. It is designed with a straight invert completely free from pockets or obstructions of any kind that might prevent the smooth flow of liquid being measured or facilitate corrosion or accumulations.

Such a form permits a gradually increasing velocity without materially decreasing the depth of liquid at the measuring section, thereby tending to provide a unit with self scouring features.

Ordinarily furnished with spigot inlet, a ball or flanged connection can be provided if desired.

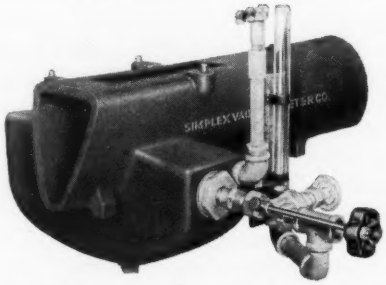


FIGURE 1.—Simplex Type S Parabolic Flume Meter for measurement of sewage and industrial wastes.

A sediment chamber of ample proportions is cast integrally with the flume and is equipped with cleaning hole, cleaning valve, blow-off valve and clear water disconnector. Levelling pins, inserted in the casting, insure installation on the proper grade.

The flume is calibrated for installation on a grade of 0.01, which is maintained regardless of the grade of the approach piping or sewer. Of extreme importance is the fact that the flume can be installed without the necessity of furnishing a section of level pipe between it and the outlet end of the pipe or sewer. Sewer slopes usually encountered do not alter the head-quantity characteristics of the flume; consequently, except in a few very unusual cases, no special regrading of the line ahead of the flume is necessary.

An added advantage is that it can be attached, by means of an eccentric increaser, to a larger diameter pipe or sewer if necessary without affecting the accuracy of measurement of liquid flow through the flume.

The type MS single water float instrument is the standard form of meter used with the parabolic flume. Adaptable in a number of ways it is furnished with floor stand or wall bracket mounting for indoor operation or, where outdoor installation is necessary, a rugged outdoor pipe leg mounted case is available. Meters of this type are suitable for mounting in manholes or above ground level. Electrical transmission can be utilized where the meter is to be located at any appreciable distance from the flume.

By virtue of the flume design and meter cam arrangement, accurate measurement over a 20 to 1 range, or from designed maximum to 5 per cent of maximum, is obtainable. A small free

fall of liquid of as little as 1 inch is all that is necessary at the flume outlet and, should the liquid at flood conditions actually back up in the flume on occasions, this will not seriously affect the accuracy of the measuring unit. Characteristics of this form of flume combined with sizes available from 6-in. diameter to 36-in. diameter permit a wide choice of capacities and enable the user to select an instrument to fit his most exacting needs.

Flumes of various sizes have been tested under a wide range of conditions at the hydraulic laboratory of the University of Pennsylvania and these tests, followed by actual installation results, have proved the theory on which the design was based to be sound in every respect.

TNEMEC COMPANY, INC.

3122 Roanoke Road, Kansas City 8, Mo.

Reserve for Rust?

Did you ever hear of a "reserve" for rust prevention? Neither have I. But the idea has always appealed to me. In some industries such as marine shipping, sewage works, certain chemical industries, etc., corrosion of metals is not only serious, it is one of the major expense items. If unchecked, corrosion will necessitate expensive repairs and even new equipment.

Surface disintegration is not limited to steel surfaces. In sewage works construction concrete plays a big part. Concrete surfaces, submerged in sewage being processed, will show surface disintegration. The more severe the exposure conditions the more rapid the surface disintegration, whether the surface is steel, concrete or other material.

Industry hopes to see a steel developed that will be corrosion-proof under the most severe conditions. It may come in the future but "in the future" does not solve the present problems. Other structural materials, such as concrete, are under constant research, seem near perfect for many uses but require surface protection against certain conditions.

One thing to be remembered is that the best preservative coating ever developed cannot restore the loss in the structure itself. Steel, eaten away by corrosion, is gone. All that a preservative coating can do is to save what is left. The longer that corrosion on steel and the disintegrating action on sewage-submerged concrete continue unchecked, the greater the cost of properly cleaning such surfaces before any preservative treatment is possible. Somewhat like a fire—once it gets going strong it is hard to stop.

Surface protection is still the only method of surface preservation and of structural preservation. It is more economical and far more satisfactory to start right, and then keep abreast of the situation by a systematic maintenance program.

Next comes the question "what coatings or paints are the best?" That's a $64.00 question. There are available a very large number of paints and coatings manufactured by firms which take pride in their products and which put out high quality merchandise. The problem goes further than that, however. A one-ton truck may be the best in its class but will break down quickly under 3-ton loads. The same applies to paint and coating products. The first need is to know what your exposure hazards are, then what type of protective coating is best adapted to protect against that exposure. Next you must decide what brand in the proper type of coating gives best performance.

BULLETIN 101

SEWAGE DISPOSAL PLANTS

GENERAL

(For New Construction. May Be used as Guide on Old Work)

A. Specify "ALL COATINGS TO BE GAS PROOF." See Catalog 45, page 3.
(a) Manufacturer's instructions and specifications for preparation of surfaces, thinning of products, etc., must be followed exactly.

B. All steel and iron (structural, windows, doors, frames, pipes, railings, etc.) to be delivered by their manufacturer or fabricator either BARE METAL or with a SHOP COAT of Tnemec 99 Metal Primer.
(a) A shop coat of Tnemec Primer to be considered as the first coat on steel or iron in these specifications, PROVIDED surfaces abraded in handling or erecting, etc., are properly wire brushed and spot coated with the same product before any further painting is done.

C. Tnemec instructions and specifications for preparation of surfaces, thinning of products, drying time, etc., must be followed exactly.

D. Surface should be DRY and CLEAN. Remove all dirt, rust, scale, loose paint and mill scale by sandblasting (always preferable) or scraping and wirebrushing. Remove grease and oil.
(a) Welds, angles, crevices and rust pits need special attention.
(b) For cleaning badly corroded steel the combination of blow torch and scraper very effective for proper and thorough cleaning.

(Paragraph references below are SPECIFICATIONS, page 10.)

STEEL AND IRON SURFACES

1. STRUCTURAL—Interior and Exterior—Atmospheric Exposure, see paragraph a.
(a) If to be encased in concrete, no painting necessary.
(b) If to be encased in brick or tile masonry, see paragraph c.

2. TANKS—(a) Underground—Interior, see paragraph b.
(b) Underground—Exterior, see paragraph b.
(c) Above ground—Interior, see paragraph b.
(d) Above ground—Exterior, see paragraph a.

3. SUBMERGED IN SEWAGE, see paragraph b.

4. WINDOWS, DOORS, CASINGS, FRAMES, etc.—Exterior, see paragraph a.
(a) Interior, except inside of office, see paragraph a.
(b) Interior, inside of office, see paragraph a or i.

5. HAND RAILS—(a) Interior, see paragraph i.
(b) Exterior, see paragraph a.

6. STEPS, GRATINGS, AND FLOOR PLATES—(a) Interior, see paragraph i.
(b) Exterior, see paragraph a.

7. PIPES—(a) Underground, see paragraph b.
(b) Interior—Atmospheric Exposure, see paragraph i.
(c) Exterior—Exposed, see paragraph a.

8. MACHINERY AND EQUIPMENT—(a) Submerged in sewage, see paragraph b.
(b) Interior—Exposed, see paragraph i.
(c) Exterior—Exposed, see paragraph a.

(BULLETIN 101 continued)

CONCRETE SURFACES

9. CHANNELS—SEWAGE—(a) Interior, see paragraph e.
(b) Exterior, see paragraph d.

10. EXTERIOR—Weather Exposed, see paragraph f.

11. TANKS—(a) Underground—Interior, see paragraph e.
(b) Underground—Exterior, see paragraph d.
(c) Above ground—Interior, see paragraph e.
(d) Above ground—Exterior, see paragraph f.

12. INTERIOR—See Floors, Walls, and Ceilings Section, paragraphs 17, 18, and 19.

WOOD SURFACES

13. EXTERIOR—Weather Exposed, see paragraph g.

14. INTERIOR—Exposed to fumes, see paragraph g.

15. INTERIOR—Office, see paragraph m.

16. WINDOWS, DOORS, CASINGS, FRAMES, etc.—Exterior, see paragraph g.
(a) Interior, except inside of office, see paragraph g.
(b) Interior, inside of office, see paragraph m.

FLOORS, WALLS AND CEILINGS

17. FLOORS—Concrete—Interior, see paragraph h.

18. CEILINGS—Interior—Concrete or Plaster, see paragraph k.
(a) Extra coat of 330 Wall Sealer specified for ceilings because they receive greater damage from rising vapors and steam.

19. WALLS—Interior—Concrete, Masonry, Plaster or Brick, see paragraph m.

20. METAL WALLS, CEILINGS, ROOFS, etc., see paragraph a.

COLORS

21. Raw Water Lines—Blue, Chlorine Lines—Green, Sewage Lines—Brown, Sludge Lines—Black, Reclaimed Sewage Water Lines—Red.

SPECIFICATIONS

(For New Construction. May Be used as Guide on Old Work)

a. One coat of 6-R or 99 Primer and Two Coats of Industrial Coating or Aluminum. See Bulletin 101 on page 35, Catalog 45.

b. One Coat of 99 Primer and Two Coats of 460 Tnemetank. See Catalog 45, pages 5 and 20.

c. First Coat of 6-R Primer and Second Coat of 5-R Black Industrial Coating. See Bulletin 101 on page 35, Catalog 45.

d. Two Coats of 437 Tnemecol. See Catalog 45, page 19.

e. One Coat of 437 Tnemecol and Two Coats of 460 Tnemetank. See Catalog 45, pages 19 and 20.

f. Neutra-Crystal Wash and Two Coats of Weatherproof Coating. See Bulletin 201 on page 43, Catalog 45.

g. Three Coats of "W" Coating. See Catalog 45, page 29.

h. One or Two Coats of Floor Coating and Finish Coat of 554 Diamond Kote. See Bulletin 202 on page 44, Catalog 45.

i. One Coat of 99 Primer and Two Coats of Industrial Enamel. See Catalog 45, pages 5 and 17.

j. First Coat of 99 Primer, Second Coat of Floor Coating and Third Coat of 554 Diamond Kote. See Catalog 45, pages 8, 15 and 16.

k. First Coat of 330 Wall Sealer, Second Coat a 50-50 mixture of 330 Wall Sealer and 607 Flat Mill White, Third Coat of 607 Flat Mill White, and Fourth Coat of Mill White (Flat, Semi-Gloss, or Gloss). See Catalog 45, pages 27 and 17.

m. First Coat, a 50-50 mixture of 330 Wall Sealer and 607 Flat Mill White, Second Coat of 607 Flat Mill White, and Third Coat of Mill White (Flat, Semi-Gloss, or Gloss). See Catalog 45, pages 27 and 17.

FIGURE 1.—Tnemec Catalog 45, available on request, affords complete and easily found information on all sewage works painting problems.

In my own 25 years of experience in connection with maintenance problems in all types of industrial plants, I have been impressed by the lack of information on the part of the majority of individuals interested in and responsible for such problems. Paint is about the very last item in a building program. Too often it appears to be the step-child in the program. "To be given two coats of paint" appears in the contract. What type of paint? How about surface preparation? A lot of things need consideration if the man who pays the bills, whether taxpayer or private owner, is to get best results.

Incidentally, we all learn by experience. What looks so promising in the laboratory does not necessarily work out in practice. Some coatings do a real job though contrary to logic. Over a period of 20 years, we have kept written records of all kinds of jobs, how surface-prepared, what combinations of coatings, how many coats. As one procedure would develop and give very good results over long periods, we would put it down in detail with the thought that any one with the same problem might find it helpful. These bulletins have now been compiled into Catalog 45, completely cross-referenced to facilitate easy use (Figure 1) and illustrated with numerous photographs and descriptive data. A copy will gladly be furnished upon request.

A. C. BEAN,
President

UNITED STATES PIPE AND FOUNDRY COMPANY

General Offices: Burlington, N. J.

Cast Iron Pipe for Sewers

The use of cast iron pipe for sewers is steadily increasing throughout the country. Many new sewage treatment plants are being built, some in conjunction with new sewer systems and others to augment existing systems. Furthermore, major revisions are being made in large numbers of existing treatment plants, not only to increase their capacity but to provide more complete treatment that will produce an effluent of better quality. Treatment costs money; the amount of money is almost directly proportional to the volume treated. Logically, therefore, every gallon of water that seeps into the mains through leaky joints, cracked pipe or from other sources not only crowds the sewer but costs good money to convey it through the various treatment stages.

Cast iron pipe possesses three outstanding properties that are most important for present day sewer construction:

1. Tight pressure type joints that prevent infiltration, thereby reducing treatment costs and incidentally eliminating trouble with tree roots.

2. Compressive strength to resist heavy earth loads due to deep fills over the pipe. Beam strength to withstand stresses caused by earth movement. Bursting strength to resist internal pressure when used as a force main or when pressure might occur temporarily due to floods.

FIGURE 1.—Installing 14-in. and 18-in. flexible joint cast iron pipe for dual line sewer siphon across the Passaic River, Fair Lawn, N. J.

3. Long life that has been proven by years of satisfactory service, consequently permitting a low amortization charge on the original investment.

There are many instances in various parts of the country where cast iron pipe has been installed in sewage works for flow mains, force mains, stream crossings (Figure 1), outfall sewers and in treatment plants.

Cast iron flow lines are generally installed where the pipe is laid in water saturated soil, to eliminate troublesome and costly infiltration.

Cast iron force mains are being installed at a steadily increasing rate due to the growing demand for sewage treatment. Treatment plants are usually located some distance away from the more densely populated sections of a community. Frequently, it is not possible to have gravity flow to the plant. In those cases the sewage flows into a sump and is then pumped through a force main to the treatment plant.

Cast iron outfall sewers have been widely and satisfactorily used to convey sewage, in most cases treated and in some cases untreated, out into a body of water for final disposal.

Cast iron pipe and fittings are used extensively to transport the sewage through the various treatment stages.

THE VAPOR RECOVERY SYSTEMS COMPANY

Compton, Calif.

Rigid Safety Tests and Examinations on Modern Sewage Gas Control Equipment

Modern requirements demand accuracy and efficiency in design, craftsmanship, and performance. The Vapor Recovery Systems Company is meeting this challenge by subjecting all its products to the most rigid safety tests known. This policy is the principle upon which "The Pace Setter Since 1928" is built.

The Flow-Testing Laboratory, an exclusive "Varec" feature, accurately calibrates the flow capacity of every "Varec" Valve, Vent, and Flame Arrester. Precision-built instruments gauge the pressure and vacuum to the exact specifications for the service recommended. Floats in "Varec" Gaslight Gauges are subjected to hydrostatic safety factors of 100 per cent above working pressure. Rigid hydrostatic and air pressure tests are made to insure vapor-tight castings, forgings, and assemblies.

"Know-how" and experience gained through the closest cooperation with sanitary engineers in the installation of over 3,000 sewage treatment plants are now incorporated in all "Varec" approved equipment. The strictest and most rigid conformity to exacting designs and specifications has developed higher quality, efficiency, and craftsmanship now available to the sewage works field.

Further research on the "Varec" approved Pressure Relief and Vacuum Breaker Valve (Fig. No. 20C) gives greater service through the use of Hycar in the seats of the hyperbolic inner valves. A synthetic rubber product, Hycar remains resilient at temperatures below zero, is highly resistant to heat and is non-soluble in sewage service. "Varec" approved drip ring eliminates condensate on the seats. Fig. No. 20C with the "Varec" approved Flame Arrester (Fig. No. 50A) form unit Fig. No. 58C, the "Guardian of Sewage Gas Control" in the treatment plant.

"Varec" Relief Valve (Fig. No. 78) is designed for use in water, oil, air,

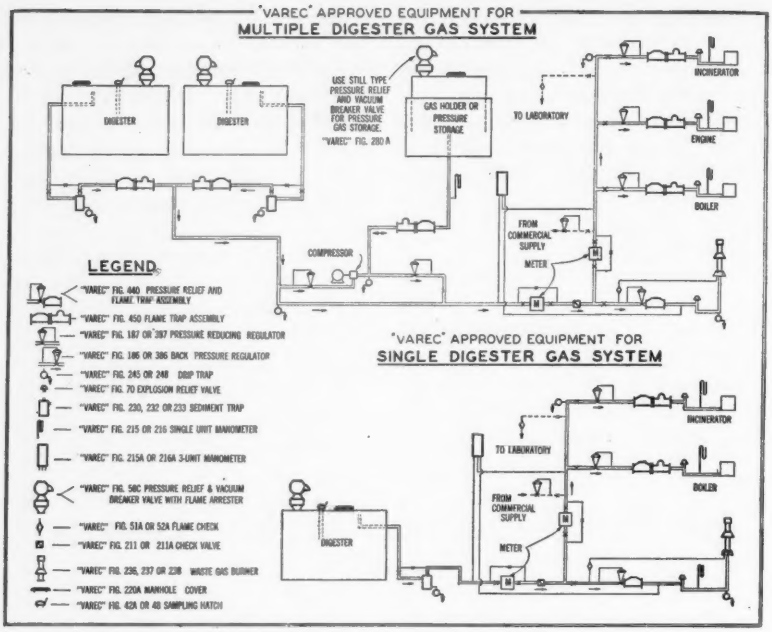

"VAREC" APPROVED EQUIPMENT FOR
MULTIPLE DIGESTER GAS SYSTEM
DIGESTER
DIGESTER
USE STILL TYPE PRESSURE RELIEF AND VACUUM BREAKER VALVE FOR PRESSURE GAS STORAGE. "VAREC" FIG. 280 A
GAS HOLDER OR PRESSURE STORAGE
TO LABORATORY
INCINERATOR
ENGINE
BOILER
FROM COMMERCIAL SUPPLY
METER
COMPRESSOR
LEGEND
"VAREC" FIG. 440 PRESSURE RELIEF AND FLAME TRAP ASSEMBLY
"VAREC" FIG. 450 FLAME TRAP ASSEMBLY
"VAREC" FIG. 187 OR 387 PRESSURE REDUCING REGULATOR
"VAREC" FIG. 186 OR 386 BACK PRESSURE REGULATOR
"VAREC" FIG. 245 OR 248 DRIP TRAP
"VAREC" FIG. 70 EXPLOSION RELIEF VALVE
"VAREC" FIG. 230, 232 OR 233 SEDIMENT TRAP
"VAREC" FIG. 215 OR 216 SINGLE UNIT MANOMETER
"VAREC" FIG. 215A OR 216A 3-UNIT MANOMETER
"VAREC" FIG. 50C PRESSURE RELIEF & VACUUM BREAKER VALVE WITH FLAME ARRESTER
"VAREC" FIG. 51A OR 52A FLAME CHECK
"VAREC" FIG. 211 OR 211A CHECK VALVE
"VAREC" FIG. 235, 237 OR 238 WASTE GAS BURNER
"VAREC" FIG. 220A MANHOLE COVER
"VAREC" FIG. 42A OR 48 SAMPLING HATCH
"VAREC" APPROVED EQUIPMENT FOR
SINGLE DIGESTER GAS SYSTEM
INCINERATOR
TO LABORATORY
BOILER
FROM COMMERCIAL SUPPLY
METER
DIGESTER

FIGURE 1.—Gas flow diagrams illustrating applications of Varec Approved Equipment.

steam or gas service. It may be installed on the discharge side of pumps and on pressure gas holder domes as safety valves. An inside spring is housed in an air-tight bonnet. The smooth-lifting valve plug is of the regrinding type. It is a sturdy, high-capacity, top-guided valve featuring an accurate spring action, easy adjustment, low percentage of "blow-down" and low maintenance costs. It seats sealtight for long extended periods of time. Adaptations and accessories make the Fig. No. 78 (inside spring) and Fig. No. 79 (outside spring) valves efficiently suited to any demands in the sewage treatment plant.

"Varec" approved Flame Trap Assembly consists of flame trap and thermal shut-off valve. Installed in all gas lines supplying gas utilization equipment, it arrests flame propagation. Non-corrosive and stainless steel construction makes inspection and maintenance simple.

"Varec" approved Pressure Relief and Flame Trap Assembly (Fig. No. 440) consists of a diaphragm operated regulator, flame trap, and thermal shut-off valve. It maintains a predetermined back pressure, passing surplus gas to burner and stops flame propagation. The patented telescopic flame trap element simplifies inspection and maintenance.

"Varec" Sensitive Pressure (Reducing) Regulator (single-port), Fig. No. 387, maintains upstream or downstream pressure to within 0.5 in. of water of predetermined pressure.

"Varec" Sensitive Pressure (Reducing) Regulator (double-port), Fig. No. 187, maintains upstream and downstream pressure to within 0.2 in. of water of predetermined pressure. Standard working parts are 18–8 S.S. with synthetic rubber diaphragm. Non-corrosive.

"Varec" Sampling Hatch Covers are installed on digester domes. Available

in several combinations of materials, non-corrosive, gas-tight, self-closing, spark-proof; Fig. No. 42A Flanged and Fig. No. 48 Screwed.

"Varec" Back Pressure Check Valve (Fig. No. 211A) is installed in relatively low pressure gas lines. Prevents back-flow through meters. Non-chattering, non-pulsating, non-corrosive and non-sparking.

"Varec" Sediment Trap and Condensate Drip Trap Assembly (Fig. No. 232D) are of cast iron construction, 18–8 S.S. working parts. Hand operated or automatic.

"Varec" Manometers (Fig. No. 216A) are accurate, with aluminum housing and bronze fittings. Pyrex glass. Automatic — fireproof — safe. Available in single or triple tubes, open or pushbutton control type.

"Varec" Manhole Covers (Fig. No. 220A) are installed on digester and gas holder domes and afford quick and easy access. Equipped with square, graphite-impregnated, fire-proof gasket, gas-tight and non-sparking.

"Varec" Waste Gas Burners (Fig. No. 236) are installed wherever disposal of surplus gas is a problem. The unit has adjustable air intake in the venturi tube, and pilot valve adjustable from the outside. Long, heavy cast iron draft stack insures proper draft and complete combustion.

"Varec" Flame Check (Fig. No. 51A) is a positive flame stop for small lines, having five 40-mesh fire screens; it is acid resisting, and affords easy inspection and maintenance.

Physical constants and characteristics of most gases are generally known, but fixed characteristics change when a fixed gas becomes mixed with foreign elements. Their reaction—even to corrosive qualities—can be determined only by thorough analyses and test investigation, because percentages by volume and varying rates of flow are important controlling factors.

All "Varec" equipment is tested to exact field application, whether for pipe line or tank. A large vessel reduces velocity head to a true static head, which is important in testing for true capacity or pressure loss.

Use of this "Varec" flow testing apparatus is offered free of charge to our customers and friends at any time for flow testing or for checking flow curves of any device. Its rated capacity is 500,000 cu. ft. per hr. of air (specific gravity 1.0) at 0.5 lb. per sq. in. pressure.

WAILES DOVE–HERMISTON CORPORATION

Westfield, N. J.

A new corrosion resisting coating with a base of highly refined coal tar pitch has been introduced by Wailes Dove-Hermiston, manufacturer of Bitumastic protective coatings.

The new product is called "Bituplastic" and has many of the characteristics of Bitumastic No. 50, a coating well known to sewage works maintenance engineers.

Both Bituplastic and Bitumastic No. 50 are cold applied, and both give a tough coat, the thickness of from 5 to 8 coats of ordinary paint, and both are brush applied in the same manner. Bituplastic, however, differs from Bitumastic No. 50 in that it can be applied with a standard spray, and it will withstand a greater temperature range; − 50° to plus 500°.

Bituplastic does not alligator in sunlight and may be painted over with decorative paints where desired. A new Bulletin No. 400, giving full particulars on Bituplastic, may be obtained from Wailes Dove-Hermiston, Westfield, N. J.

WALKER PROCESS EQUIPMENT, INC.

Aurora, Illinois

Impingement Aeration

Multiple Advantages for the Activated Sludge Process

Walker Process Equipment, Inc. offers to the sewage and waste treatment field for the activated sludge process a new aeration unit—"The Impingement Aerator." This revolutionary design replaces the diffuser tube and plate systems accepted for years as the universal means for air diffusion.

The principle of air diffusion involved consists of combining a water jet and a stream of large air bubbles in such a manner that the bubbles are diffused in pin-point size (Figures 1 and 2).

Functioning of a Unit

The functioning of the unit is simple and trouble-free. Settled sewage or aeration tank liquor is pumped under a pressure of 4 p.s.i. into the water manifold of the assembly. Compressed air is pumped through the air manifold at just enough pressure to overcome the aeration tank water depth. Compressed air, bubbling from beneath the impinger, is entrained and broken into small particles by the shearing action of the impingement water. The air-water mixture then diffuses into the aeration tank, causing circulation and aeration of the tank contents.

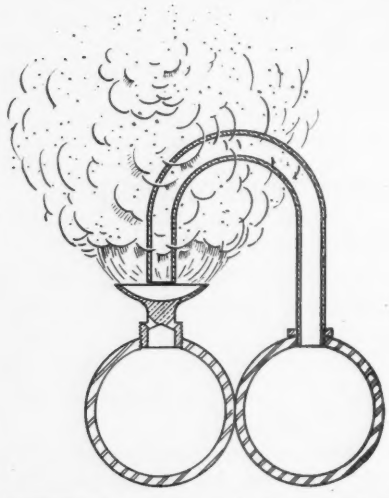


FIGURE 1.—The principle involved consists of a water jet, impinging on a hydraulic bowl placed over an air stream. This causes physical contact and shearing between the two masses at the bowl periphery.

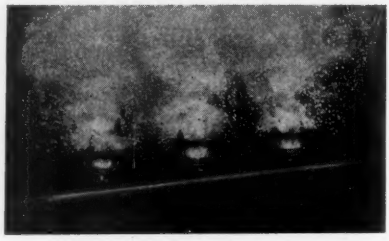


FIGURE 2.—Individual impingement units are mounted on laterals, which diffuse a widespread continuous air pattern.

Impingement liquid is generally pumped from the aeration tank or may be pumped as returned activated sludge, or both.

Air filters ahead of the blower are not required since there are no small air orifices to protect from clogging.

Oxygen Absorption

The volume of air required to operate this unit, due to much greater oxygen absorption, is less than that required for conventional porous diffusion units. The amount of impingement water used ordinarily amounts to no more than that required for return activated sludge. Consequently, the overall power required is less than that required for conventional diffuser methods and compares favorably with that required for mechanical aeration.

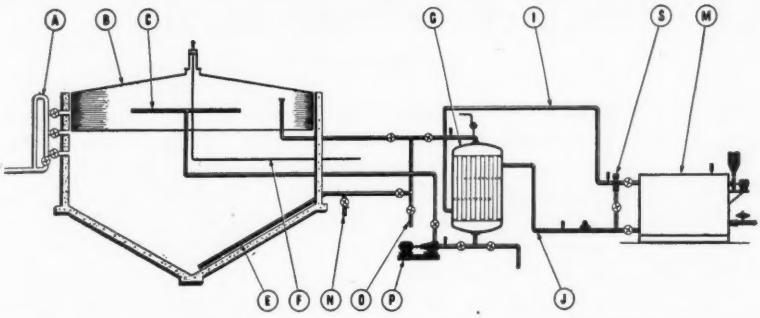


FIGURE 3.—A—supernatant draw-off; B—gas holder; C—heated sludge distributor; E—sludge draw-off; F—gas line to immersion burner; G—heat exchanger; I—heating water supply; J—heating water return; M—immersion heater boiler; N—outlet to sludge beds; O—inlet from raw sludge pump; P—recirculating pump; S—3-way blending valve.

Maintenance

The maintenance problem resulting from clogged pores in diffuser tubes and plates is eliminated with the Impingement Aerator. Because the air discharge holes are large, they do not clog and do not require either air filters or periodic cleaning.

Installation

The standard assembly arrangement for the Impingement Aerator is in a fixed position near the bottom of the tank. To meet individual job requirements, other positions can be used.

Existing installations of porous tubes and plates can be rehabilitated by replacement with Impingement Aerators. Existing air lines, control valves and blowers will be utilized whenever such a conversion is made. It is required only to add a low pressure impingement water pump and simple water header piping.

Digester Heat Exchanger System

Figure 3 is a pipe diagram of a typical recommended digester heating and sludge recirculation layout. The general method shown has been in successful use since 1940 at Webster City, Iowa.

This arrangement is advantageous since either 180° F. jacket water (from gas engines or from the hot water boiler) may be used directly in the exchanger without overheating the sludge or caking on the exchanger tubes. Counter current vertical heating and compensating pressure drop insures uniform displacement through the exchanger tubes.

The modern industrial type suction immersion burner economizes on fuel to the utmost and eliminates ordinary gas boiler maintenance.

The thermostatically controlled 3-way valve gives automatic temperature control over the heating system. This allows unrestricted use of hot water for space heating.

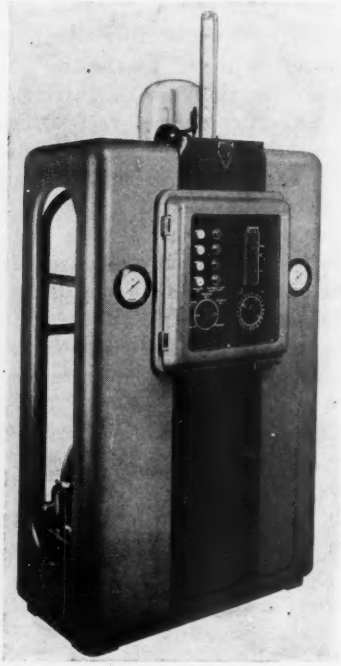
Gas engine jacket water may be directly cross connected into the heating water system.

WALLACE & TIERNAN CO., INC.

Newark 1, N. J.

Sewage chlorination, once considered a "luxury" item in sewage treatment, has, in the last few years, made such advances and has proved itself such a versatile tool of the sewage works operator that it is now generally recognized as an indispensable part of a modern sewage treatment plant.

In general, sewage chlorination can be divided, by purpose, into three major categories. First, there is what might be called "esthetic chlorination" including chlorination for odor control. Second, there is "process chlorination," employed in various ways, such as to control sludge bulking, to aid in the treatment process and make satisfactory sewage disposal easier and more economical. Thirdly, there is what is rapidly getting to be "required chlorination" in the form of effluent sterilization to reduce stream pollution.



W & T Program Controlled Sewage Chlorinator

Aside from increasingly stringent pollution abatement regulations, however, effluent chlorination is almost mandatory if a community is to preserve for itself and its visitors attractive bathing beaches, fishing spots and camping and other recreation areas. In a sense, the same principle applies as well to the other types of chlorination. Modern society demands unobtrusive, efficient and economical sewage disposal from house to point of discharge and that's why more and more sewage plants are turning to the aid of chlorination in meeting this challenge.

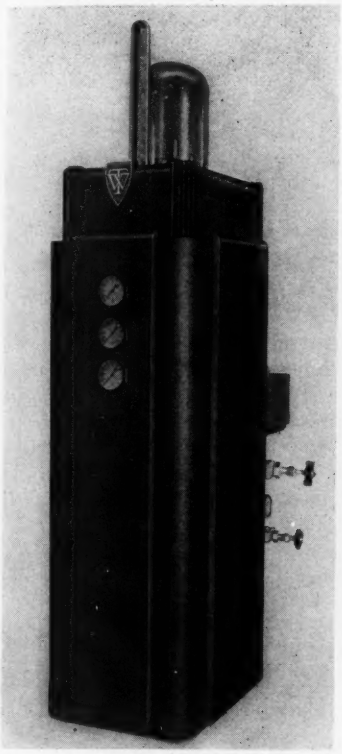
Considered from the standpoint of location—or point of application—many of the specific benefits of sewage chlorination may be shown. For example:

Interceptor Chlorination is employed to control odors, prevent septicity and reduce hydrogen sulfide damage to concrete structures.

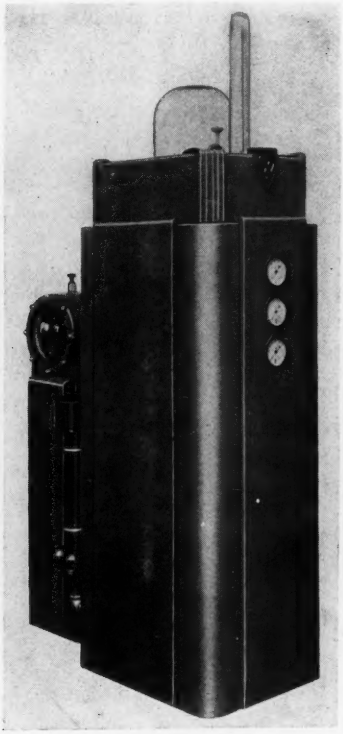
Plant Chlorination serves many purposes including odor control, elimination of hydrogen sulfide corrosion, prevention of filter ponding and sludge bulking, improved settling and digester supernatant treatment.

Effluent Chlorination gives B.O.D. reduction—particularly important to plants discharging into watercourses having seasonal flow variations, protects downstream water intake and keeps bathing and fishing areas in shape as healthful, pleasant recreation attractions.

To meet the various requirements of sewage chlorination, W & T has a full line of chlorination equipment ranging from Hypochlorinators to high capac-



W & T Visible Vacuum Chlorinator



W & T Automatic Proportional Flow Chlorinator

ity Visible Vacuum Chlorinators. Controls on most types can be supplied for manual, automatic start and stop or full automatic proportional flow operation. The newest W & T Sewage Chlorinator is a program controlled unit, designed especially to meet the unusual conditions encountered in sewage chlorination.

Each type of chlorination and each treatment plant presents particular problems, but for every case there's a job-engineered W & T Chlorinator and the more than 30 years' experience of W & T Chlorination Specialists. For detailed recommendations on *your* sewage chlorination problems without obligation just communicate with any W & T representative or with Wallace & Tiernan, Newark 1, N. J.

YEOMANS BROTHERS COMPANY

1411 N. Dayton St., Chicago 22, Ill.

SEWAGE TREATMENT EQUIPMENT, SEWAGE PUMPS, PNEUMATIC SEWAGE EJECTORS, ROTARY AIR COMPRESSORS, VACUUM PUMPS

Aero-Filters

The most recent addition to Yeomans' comprehensive line of pumps and sewage treatment equipment is the high capacity Aero-Filter. This highly successful method of biological filtration was developed by Dr. H. O. Halvorson of the University of Minnesota in collaboration with R. L. Smith, consulting engineer, St. Paul, Minnesota, and has been in commercial use since 1936.

The well deserved popularity of the Aero-Filter has been gained through recognition of the many advantages of this type of sewage treatment over conventional trickling filter methods. With all other considerations being equal, the advantage of the Aero-Filter over the conventional filter in construction cost alone would be sufficient to warrant its present popularity. Results comparable to and in many cases superior to the conventional filter are obtained by Aero-Filters having only one-seventh the quantity of filtering material required by the conventional filter.

The obvious saving in filtering material, underdrain and encircling concrete wall are realized through the increase in permissible B.O.D. loading in the Aero-Filter. Loadings up to 2 lb. B.O.D. per cubic yard of rock are recommended for the Aero-Filter as compared to 0.25 lb. per cubic yard in the conventional filter. The 2 lb. per cubic yard loading corresponds approximately to a loading of 3,000 lb. per acre-foot, and in many cases the Aero-Filter has been subjected to loadings of 4,500 lb. per acre-foot without seriously affecting the overall reduction being obtained, clearly demonstrating its ability to withstand shock loads without adverse affect.

The high unit loading in the Aero-Filter without recirculation for dilution purposes is a result of the method of applying the settled sewage to the filter, for the method and rate of application is the basis of the Aero-Filter process. Other high capacity filters employ dilution of the settled sewage by recirculation of large quantities of filter or final effluent, whereas the Aero-Filter employs recirculation only during periods of low sewage flow and in the minimum quantity required for proper operation of the distributor.

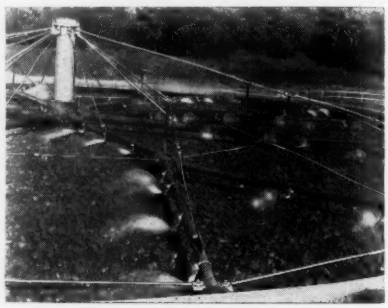


FIGURE 1.—Aero-Filter employing multiple arm distributor.

It has been demonstrated that ideal conditions of filter operation can be achieved if the sewage is applied continuously and uniformly over every square foot of filter surface during every second of the day, since it is an established truth that bacterial growths developed in the filtering material do not require rest periods between feedings. The ideal condition could be attained by a method of continuous distribution which would apply the sew-

age in a mist or rain-drop form over the entire filter surface.

Aero-Filter distributors have been designed to effect, as nearly as possible, the ideal conditions of distribution. The motor driven disc distributors for filter beds of small diameter apply the sewage in a rain-drop form continuously over every square foot of filter surface. For beds of larger diameter the multiple arm distributor (Figure 1), operated at 2 to 3 r.p.m. and equipped with centrifugal type nozzles to reduce the applied sewage to rain-drop proportions, produces comparable results.

Since Aero-Filter applies the sewage in a thin film it is not necessary to practice recirculation for the purpose of diluting the applied sewage or providing the flora with sufficient opportunities for completion of their work. Recirculation is required only during periods of low sewage flow and then only in an amount necessary to maintain a minimum rate for proper operation of the distributor. However, in cases where very strong sewage is being treated and a high degree of treatment is required, recirculation is recommended in an amount dictated by the strength of the sewage being applied.

An Aero-Filter plant designed on the basis of a maximum loading of 2 lb. of settled sewage B.O.D. per cubic yard of filter media will provide an overall B.O.D. reduction of 84 to 88 per cent without the use of recirculation for dilution purposes. Design recommendation is 1.86 lb. of settled sewage B.O.D. per cubic yard of filter media, which is equivalent to a loading of 3,000 lb. per acre-foot.

For raw sewage strengths in excess of 250 p.p.m., when a high degree of treatment is required, multiple stage design is recommended. Multiple stage design is also recommended for all cases of raw sewage strength in excess of 400 p.p.m. Rates of application should be between 10 m.g.a.d. and 30 m.g.a.d. at the 24-hour average rate of flow, with 18 m.g.a.d. being preferred. Minimum rates should range between 10 m.g.a.d. and 15 m.g.a.d., with 13 m.g.a.d preferred.

Professional Opportunities

Biochemist to be in charge of city laboratory conducted for the purpose of studying lake and stream pollution problems; salary $400 to $500 per month plus present cost-of-living salary adjustment of $48.96 a month; must be a graduate of an accredited college or university with post graduate training equivalent to a Masters degree but preferably a Ph.D., majoring in one of the sanitary sciences, preferably sanitary chemistry or sanitary engineering. At least two years practical experience required in biological laboratory studies of lake and stream pollution or comparable experience. Write Personnel Department, City Hall, Madison 3, Wis.

Research Assistant for the Department of Civil Engineering, Georgia School of Technology, Atlanta, needed immediately. Opportunity for young chemist or engineer to work toward advanced degree while obtaining teaching experience. For further information write George W. Reid, Associate Professor, Georgia School of Technology, Civil Engineering Department, Atlanta, Ga.

District Sanitary Engineer for the Alaska Territorial Department of Health to be responsible for the sanitary control, design, construction and operation of water and sewage works in an assigned area and to supply technical supervision for sanitary engineers and sanitarians in one or more sanitation districts; salary (base) $365 to $410 per month plus differential; must have at least a bachelor's degree in engineering, with emphasis on public health and sanitary engineering, from a recognized college or university, and must have four years experience therein; must be able to satisfy the requirements of a registered professional engineer in the Territory of Alaska; must be able to travel a large part of the time. Airmail correspondence to Amos J. Alter, Territorial Department of Health, Territorial Building, P.O. Box 1931, Juneau, Alaska.

Senior Sanitary Engineer for the Alaska Territorial Department of Health to plan and carry out programs in the fields of sanitary engineering and environmental sanitation, particularly as they apply to the supervision of public water supply and waste disposal facilities, etc.; salary (base) $342 to $387 a month plus differential; must be graduate of a recognized college or university in civil, chemical, mechanical or sanitary engineering, including one academic year of public health training; four years experience are required; must be able to travel a large part of the time. Airmail correspondence to Amos J. Alter, Territorial Department of Health, Territorial Building, P.O. Box 1931, Juneau, Alaska.

Sanitarian for the Alaska Territorial Department of Health to plan and carry out programs in the field of environmental sanitation particularly as they apply to the supervision of milk and other food products, including inspection of food handling establishments, schools, institutions, etc.; salary (base) $300 to $345 a month plus differential; must be a graduate of recognized college or university with B.S. degree, with major work in biological sciences, chemistry, physics, etc.; must have one academic year of public health training and at least two years experience; must be able to travel a large part of the time. Airmail correspondence to Amos J. Alter, Territorial Department of Health, Territorial Building, P.O. Box 1931, Juneau, Alaska.